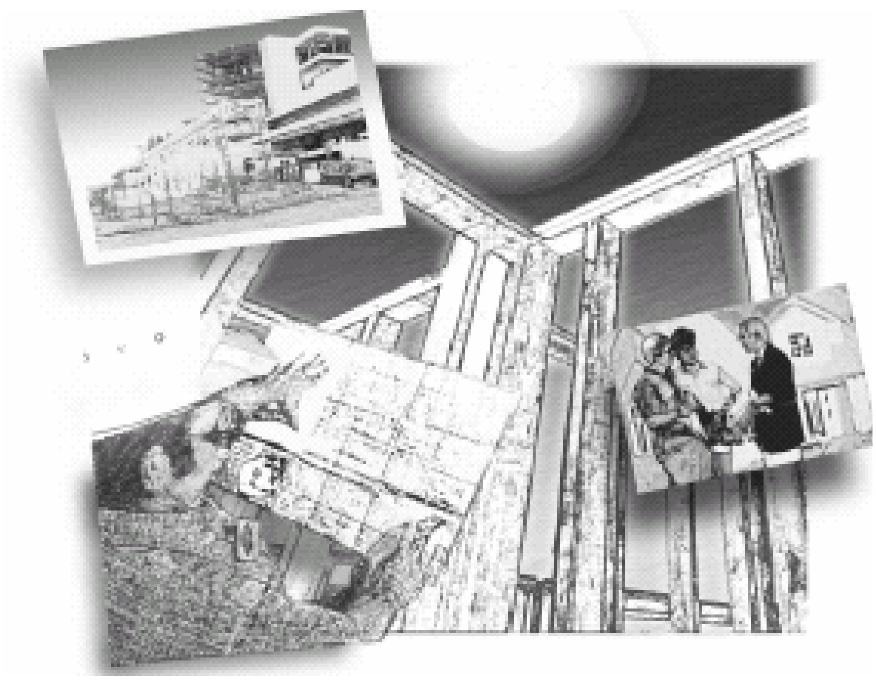
RESIDENTIAL ALTERNATIVE CALCULATION METHOD (ACM) APPROVAL MANUAL

for the

2005 BUILDING ENERGY EFFICIENCY STANDARDS FOR RESIDENTIAL AND NONRESIDENTIAL BUILDINGS

CALIFORNIA
ENERGY
COMMISSION

STANDARDS/REGULATIONS



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Arnold Schwarzenegger, *Governor*

NOTICE

This version of the *2005 Residential Alternative Calculation Method (ACM)Approval Manual for the Building Energy Efficiency Standards* is an "unmarked" version; that is, it contains no underlined or struck-out text showing changes from the 2001 Standards (the changes are incorporated, however). A marked version is available on the Energy Commission's website or in hard copy from the Commission's Buildings and Appliances Office. Visit www.energy.ca.gov/title24, call the Title 24 Energy Efficiency hotline at 800/772-3300 (toll-free from within California) or 916/654-5106, or send email to title24@energy.state.ca.us.

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1. Overview

This Manual explains the requirements for approval of residential *Alternative Calculation Methods* (ACMs). Residential ACMs are used to demonstrate compliance with the performance approach to the California Energy Efficiency Standards for Low-Rise Residential Buildings.

The approval procedure is one of self-testing and self-certification by the ACM vendor. The vendor conducts the specified tests, evaluates the results and certifies in writing that the ACM passes the tests. The California Energy Commission (Commission) will perform spot checks and may require additional tests to verify that the proposed ACM is suitable for compliance purposes. The vendor is required to develop a compliance supplement (program user manual) explaining how to use the program for showing compliance with the standards. The compliance supplement will also be checked by the Commission for accuracy and ease of use.

When energy analysis techniques are compared, there are two basic sources of discrepancies: differences in user interpretation when entering the building specifications, and differences in the ACM's algorithms for estimating energy use. The approval tests in this manual are designed to minimize differences in interpretation by providing explicit detailed descriptions of the test buildings that shall be analyzed.

This chapter presents the general requirements for residential ACMs. Appropriate inputs for all modeling capabilities are discussed in Chapter 2. Chapter 3 has the rules for defining the *Standard Design*. Chapter 4 has algorithms and modeling assumptions used in the reference method. Chapters 5 and 6 have accuracy tests. Chapter 7 has requirements for field verification and diagnostic testing. Chapters 8 and 9 have requirements for ACM vendors.

1.1 Minimum Modeling Capabilities

Minimum modeling capabilities shall be included in all ACMs. If a candidate ACM does not have all of these capabilities, then it cannot be approved for compliance. The minimum modeling capabilities are summarized below:

- Conduction gains and losses through opaque and fenestration surfaces.
- Infiltration gains and losses
- Solar gains through glazing including the effects of internal shading devices, external shading devices and fixed overhangs.
- Natural ventilation cooling and natural ventilation for Indoor Air Quality (IAQ).
- Mechanical Ventilation for IAQ.
- Thermal mass effects to dampen temperature swings.
- Space conditioning equipment efficiency and distribution systems.
- Water heating equipment efficiency and distribution systems.
- Radiant Barriers
- Cool Roofs
- Maximum Cooling Capacity

1.2 Optional Modeling Capabilities

Candidate ACMs may have more capabilities than the minimum required. ACMs can be approved for use with none, a few, or all of the optional capabilities. The following optional capabilities are recognized for residential ACMs:

- Raised floors with automatically operated crawl space vents.
- Zonal control or multi-zone modeling of the sleeping and living areas of the house.
- Attached sunspaces for collection and possible storage of heat for transfer to the main house.
- Exterior mass walls.
- Side Fin Shading.
- Combined hydronic space and water heating.
- Building additions.
- Solar water heating.
- Form 3 report generator.
- Gas-Absorption Cooling

Many of the optional modeling capabilities have been previously approved by the Commission through the exceptional methods process. The approval tests for optional modeling capabilities are included in Chapter 6.

1.3 Application Checklist

The following is a checklist of all the items that shall be included in an application package for ACMs. Some materials are required only for general purpose ACMs and are so indicated.

- *ACM Vendor Certification Statement.* A statement from the ACM vendor certifying the ACM, and, its reliability and accuracy when used for compliance purposes (see ACM RA-2005).
- *Computer Run Summary Sheets.* Hard copy summary sheets of all the required computer runs (see ACM RA-2005).
- *Computer Runs.* Copies of the computer runs specified in Chapters 5 and 6 of this Manual, including complete input and output files, on diskettes or in computer readable form acceptable to the Commission to enable spot checks.
- *Compliance Supplement.* A copy of the Compliance Supplement discussed in Chapter 8. The Compliance Supplement and the ACM User's Manual may be combined into the same document.
- *Copy of the ACM.* A magnetic media copy of the ACM (in a format agreed to by the Commission staff) for verification of analyses and random verification of compliance analyses. Weather data shall be included.
- *Application Fee.* An application fee of $1,000.00 (one thousand dollars) is required to cover costs of evaluating the application.

1.4 Types of Approval

This Manual addresses three types of ACM approval: full approval, streamlined approval of new program features, and amendments to full approvals.

1.4.1 Full Approval

Full approval is required when a candidate ACM has never been previously approved by the Commission, and/or when the ACM vendor makes changes to the executable program code or algorithms, or any other change that in any way affects the results. The Commission may also require that all ACMs be approved again when the standards are updated on the three-year cycle or whenever substantial revisions are made to the approval process, for instance, if new analysis capabilities come into widespread use, and the Commission declares them to be minimum capabilities for all ACMs.

When re-approval is necessary, the Commission will notify all ACM vendors of the timetable for renewal. There will also be a revised ACM Approval Manual published, with complete instructions for re-approval.

Full approval is required for all ACM changes, unless they qualify for the streamlined approval process or for an addendum, as discussed below.

1.4.2 Streamlined Approval

Certain types of changes may be made to approved residential ACMs through a streamlined procedure. Examples of changes that qualify for streamlined approval are modifications to the user interface or implementation on a different operating system as long as there are no changes to the executable program code that would in anyway affect the results.

If an ACM modification qualifies for streamlined approval, then the following procedure is followed:

- The ACM vendor prepares an addendum to the compliance supplement, when appropriate, describing the change to the ACM.
- The ACM vendor notifies the Commission by letter of the change. The letter shall describe in detail the nature of the change and why it is being made. The notification letter shall be included in the Compliance Supplement.
- Provide the Commission with an updated copy of the ACM and include any new reports created by the ACM (or modifications in the standard reports).
- The Commission responds in 45 days. The Commission response may take several forms. The Commission may request additional information, refuse to approve the change or require that the ACM vendor make specific changes to either the Compliance Supplement addendum or the ACM.
- With Commission approval, the vendor may issue new copies of the ACM with the Compliance Supplement addendum and notify ACM users and building officials.

1.4.3 Amendments

An ACM approval shall be amended when optional modeling capabilities are added. The vendor shall provide the additional computer runs required for the optional modeling capability. It is not necessary to include computer runs previously submitted.

An amendment to an approved ACM shall be accompanied by a cover letter explaining the type of amendment requested, and copies of other documents as necessary. All items on the application checklist should be submitted, when applicable. The timetable for approval of amendments is the same as for full approval.

1.4.4 When Approval Is Not Required

Changes that do not affect compliance with the Energy Efficiency Standards for Residential Buildings do not require full or streamlined approval. However, the ACM vendor shall notify the Commission and provide the Commission with an updated copy of the program and user manual. Re-approval is required for any ACM program change that affects the energy use calculations for compliance, the modeling capabilities for compliance, the format and/or content of compliance forms, or any other change which would affect a building's compliance with the Standards. Any questions regarding applicable approval procedures should be directed to the Commission.

1.5 Challenges

Building officials, program users, program vendors or other interested parties may challenge any residential ACM approval. If any interested party believes that a compliance program, an algorithm, or method of calculation used in a compliance program, a particular capability or other aspect of a program provides inaccurate results, the party may challenge the program.

1.6 Decertification of ACMs

The Commission may *decertify* (rescind approval of) an alternative calculation method through various means:

- All ACMs are decertified when the standards undergo substantial changes, which usually occurs every three years.
- Any ACM can be decertified by a letter from the ACM vendor requesting that a particular version (or versions) of the ACM be decertified. The decertification request shall briefly describe the nature of the program errors or "bugs" which justify the need for decertification.
- Any "initiating party" may commence a procedure to decertify an ACM according to the steps outlined below. The intent is to include a means whereby serious program errors, flawed numeric results, improper forms and/or incorrect program documentation not discovered in the certification process can be verified, and use of the particular ACM version discontinued. In this process, there is ample opportunity for the Commission, the ACM vendor and all interested parties to evaluate any alleged errors in the ACM program.

Process. Following is a description of the process for challenging an ACM or initiating a decertification procedure:

1. Any party may initiate a review of an ACM's approval by sending a written communication to the Commission's Executive Director. (The Commission may be the initiating party for this type of review by noticing the availability of the same information listed here.)

   The initiating party shall:

   (a) State the name of the ACM and the program version number(s) which contain the alleged errors;

   (b) Identify concisely the nature of the alleged errors in the ACM which require review;

   (c) Explain why the alleged errors are serious enough in their effect on analyzing buildings for compliance to justify a decertification procedure; and,

   (d) Include appropriate data electronically (in a format agreed to by the Commission staff) and/or information sufficient to evaluate the alleged errors.

2. The Executive Director shall make a copy or copies of the initial written communication available to the ACM vendor and interested parties within 30 days.
3. Within 75 days of receipt of the written communication, the Executive Director may request any additional information needed to evaluate the alleged ACM errors from the party who initiated the decertification review process. If the additional information is incomplete, this procedure will be delayed until the initiating party submits complete information.
4. Within 75 days of receipt of the initial written communication, the Executive Director may convene a workshop to gather additional information from the initiating party, the ACM vendor and interested parties. All parties will have 15 days after the workshop to submit additional information regarding the alleged program errors.
5. Within 90 days after the Executive Director receives the application or within 30 days after receipt of complete additional information requested of the initiating party, whichever is later, the Executive Director shall either:

   (a) Determine that the ACM need not be decertified; or,

   (b) Submit to the Commission a written recommendation that the ACM be decertified.

6. The initial written communication, all other relevant written materials and the Executive Director's recommendation shall be placed on the consent calendar and considered at the next business meeting after submission of the recommendation. The matter may be removed from the consent calendar at the request of any person.

7. If the Commission approves the ACM decertification, it shall take effect 60 days later. During the first 30 days of the 60 day period, the Executive Director shall send out a Notice to Building Officials and Interested Parties announcing the decertification.

All initiating parties have the burden of proof to establish that the review of alleged ACM errors should be granted. The decertification process may be terminated at any time by mutual written consent of the initiating party and the Executive Director.

As a practical matter, the ACM vendor may use the 180- to 210-day period outlined here to update the ACM program, get it re-approved by the Commission, and release a revised version that does not contain the bugs initially brought to the attention of the Commission. Sometimes the ACM vendor may wish to be the initiating party to ensure that a faulty program version is taken off the market.

1.7 Alternative ACM Tests

This Manual provides tests to verify that ACMs are accurate. These tests are provided in Chapters 5 and 6 of the Manual. An ACM vendor may propose alternate tests when the vendor believes that one or more of the standard tests are not appropriate for the ACM. Alternate tests will be evaluated by the Commission and will be accepted if they are considered reasonable. If accepted, the alternate test(s) will be added to this manual as an addendum and the alternate test(s) will be available for use by all ACMs. The alternate test will coexist with the standard test presented in this Manual until the Manual is revised. When a new version of this Manual is produced, the alternative test may be substituted for the current test or may continue to coexist with the original test.

1.8 Approval of New Exceptional Methods

The Commission may approve new exceptional methods. Exceptional methods are special modeling capabilities or calculation methods necessary to recognize building features that cannot be adequately modeled with existing ACMs. When an Exceptional Method is approved, a new optional capabilities test may be approved as part of the process. Exceptional Methods do not necessarily produce optional capabilities for ACMs. For instance, radiant heating systems are recognized by an adjusted equipment efficiency that may be used directly in ACMs or other compliance methods. To be approved for the new optional capability, vendors shall amend their ACM approval.

Even if an ACM already incorporates the Exceptional Method, the vendor shall receive approval to use the Exceptional Method in the compliance process. The ACM vendor shall demonstrate that the ACM automatically uses the correct fixed and restricted inputs for the Exceptional Method and that the standard reports identify the building feature(s) recognized by the Exceptional Method. Additionally, the ACM compliance supplement shall be updated, referencing the use of the new Exceptional Method.

To receive a copy of the Exceptional Method contact the Residential Office at (916) 654-4064.

2. Standard Reports

2.1 General

For consistency and ease of enforcement, the manner in which building features are reported by ACMs is standardized. This section of the ACM Approval manual describes the required standard reports. All residential ACMs shall automatically produce compliance reports as specified in this Chapter. These *Standard Reports* are required to enable building officials to evaluate the results from ACMs without having to learn each computer program. Included in every compliance package will be reports CF-1R and other related forms, which are described in detail below.

The CF-1R shall have two highly visible sections, one for *Special Features and Modeling Assumptions* and a second for features requiring *Field Verification and Diagnostic Testing*. These two sections serve as "punchlists" during compliance verification by the local building department. Items listed in the *Special Features and Modeling Assumptions* section indicate the use for compliance of unusual features or assumptions, and call for special care by the local building department. Items listed in the *Field Verification and Diagnostic Testing* section are for features that require diagnostic testing or independent verification to insure proper field installation in addition to local building department inspection.

Only user inputs are described and included in the standard reports. The fixed and restricted inputs are not included in the standard reports since ACMs shall be designed so that the fixed and restricted inputs and default values in the absence of specific user input are automatically used when the program is used for compliance.

The structure and organization of the Standard Reports described in the subsequent sections should be followed as closely as possible. The reports are divided into tabular listings that have a title, column headings and data entries. The data entries shown in the listings that appear in this manual are typical values and are included only to illustrate the report format; they are not default values and cannot be assumed to be in compliance with the standards. The specification of the category or type of data expected in each field is provided in the list of definitions associated with each column heading. The type of data entries will be one of the following:

- Text: A variable-length text field input by the user.
- Recommended Descriptor: An abbreviation or short name from lists or tables of permissible types provided within this manual (e.g., LgStoGas). Only types found in these lists or tables may be used. Different descriptors may be used by the ACM as long as they are reasonable descriptors for the list entry item and are not misleading. In some cases where the descriptor is a short complete word, the descriptors are prescribed and shall be used. Even for prescribed descriptors some discretion is allowed. For example, for tables with long rows Y may be used for the prescribed descriptor Yes. User-defined descriptors may NOT be used but rather shall be automatically assigned by the ACM based upon user input. For example, UWALL01 may be assigned by the ACM to the first user-defined wall type.
- Filename.ext: The name of the input or output file
- Dimensions or units of measure, such as "hr-ft^2-°F /Btu", ft^2, etc.
- Num: A cardinal or ordinal number.

Deviations from the standard reports will be approved by the Commission on a case-by-case basis when they are necessary because of conceptual differences between ACMs or because of special modeling features. The categories of information represented in the tables and the standard headings shall not be changed. Additional columns or additional tables may be added when necessary and column headings may be abbreviated, and reports may be reformatted with different character spacing, line spacing, row heights or column widths to permit better readability or paper conservation. ACMs may also provide additional customized information at the bottom of the standard reports, separated from the standard report by a line.

Some of the tables in the standard reports are not applicable for all buildings. When a table is not applicable for a particular building, it should be omitted. When one of the standard tables is included, all the columns should be included (although column width may be reduced), even if some of the information in the columns is not applicable to the proposed design.

The Standard Reports are designed to accommodate the optional modeling capabilities included in this manual. Approval of additional optional modeling capabilities may require modification of the standard report format.

2.2 Certificate of Compliance –Residential Computer Method (CF-1R)

The Certificate of Compliance (report CF-1R) is the principal standard report that shall be produced. The Certificate of Compliance is required by the Administrative Requirements (Title 24, Section 10-103).

The CF-1R (Residential Computer Method) shall include all information provided by the program user. If the standard report does not fully document all user inputs, additional tables or notes shall be added by the program vendor to fully document all user inputs.

Information on the Certificate of Compliance is provided below to illustrate the use of all the standard tables.

2.2.1 Report Headings

The following heading shall appear on the first page.

CERTIFICATE OF COMPLIANCE:
RESIDENTIAL COMPUTER METHOD

Page 1 of 4

Project Title	Filename:	Date:
Project Address	Run Title:	<runcode>
Documentation Author		<initiation time>
Telephone		Building Permit #
Compliance Method		Plan Check / Date
Location/Climate Zone		Field Check/ Date

The Filename, Run Title, Runcode, and Initiation Time need not appear in the header as shown above but shall appear as part of the header information for all pages of the Certificate of Compliance.

The following heading shall appear on subsequent pages.

CERTIFICATE OF COMPLIANCE:
RESIDENTIAL COMPUTER PERFORMANCE

Page 2 of 4

Project Title	Filename:	Date:
	Run Title:	<runcode/initiation time>

- *Project Title, Date, Project Address, Documentation Author and Telephone, and Climate Zone (text):* Display user inputs for these fields.
- *Filename (filename.ext):* The filename of the input file used to generate the compliance form.
- *Compliance Method (te*xt): The Alternative Calculation Method program name and version number.
- *<Runcode/Initiation Time> (alphanumeric text):* A unique runcode designation generated automatically by the ACM to identify the specific run. This number and the initiation time changes with each run initiated by the user even though the filename and Run Title may remain the same. The initiation time is the time (including the hour and minute) that the compliance run was initiated by the user.
- *Run Title (text):* Optional user input item. Use for commentary or description of unique characteristics of a particular run.

2.2.2 Energy Use Summary

This section compares the energy use of the proposed building to the energy budget of the standard design building. All units in this table are TDV (time dependent valuation) energy (kBtu/ft²-yr). Energy is shown for space heating, space cooling and hot water. The space heating and cooling energy budgets are determined from the standard design using the custom budget method. The water heating budget is calculated from the custom budget water heating calculation methods described in this document. ACM vendors may add additional columns or rows to this report when appropriate, such as for multi-zone building analyses or breaking out energy use components such as HVAC fans.

TDV ENERGY USE SUMMARY (kBtu/ft^2-yr)

	Standard Design Energy Budget	Proposed Design Energy Use
Space Heating	23.45	21.23
Space Cooling	10.34	8.23
Water Heating	15.90	14.67
Total	49.69	44.13

Additional rows may be added to the table when necessary to accommodate energy uses that are to be included in the analysis but cannot be easily assigned to one of the three principal categories. Examples of possible additional rows might include separating fan energy (typically included with cooling) or recirculating pump energy.

2.2.3 General Information

This listing in the Certificate of Compliance follows the first page heading and provides basic information about the building. A description of these data elements is given later in this chapter.

GENERAL INFORMATION

HERS Field Verification/Diagnostic Testing Required for Compliance	Yes
Conditioned Floor Area:	1384 ft^2
Average Ceiling Height	10.2 ft.
Building Type:	Single Family
Building Front Orientation:	15 deg (North)
Glazing Area as % of Floor Area	14.4%
Average Fenestration U-factor	0.52
Average Fenestration SHGC	0.60
Number of Dwelling Units:	1
Number of Stories:	2
Floor Construction Type:	Slab on grade
Number of Conditioned Zones:	2
Total Conditioned Volume:	11072 cf
Conditioned Slab Floor Area:	1384 ft^2
Total Conditioned Floor Area:	1384 ft^2

- *HERS Field Verification/Diagnostic Testing Required For Compliance (yes or no).* At the very beginning of the Certificate of Compliance, this provides a prominent notification when compliance with the performance standards requires HERS Rater field verification or diagnostic testing.
- *Conditioned Floor Area.* The conditioned floor area of all building zones modeled in the computer run.
- *Building Type.* The type of building. Possible types are single-family and multi-family.
- *Construction Type.* The type of construction. Possible types are new, existing, addition alone and existing plus addition plus alteration.
- *Building Front Orientation.* The azimuth of the front of the building. This will generally be the side of the building where the front door is located. A typical reported value would be "290° (west)". This would indicate that the front of the building faces north 70° west in surveyors terms. The closest orientation on 45° compass points should be verbally reported in parenthesis, e.g. north, northeast, east, southeast, south, southwest, west or northwest. When compliance is shown for multiple orientations, "all orientations" may be reported. When "all orientations" is reported it shall be included in the *Special Features and Modeling Assumptions* listing.
- *Number of Dwelling Units.* The total number of dwelling units in the building. This number may be a fraction for cases of addition alone.
- *Number of Stories*. The number of building stories as defined by the *California Building Code*.
- *Floor Construction Type.* The ground floor construction type is one of the factors considered when determining the amount of thermal mass in the *Standard Design*.
- *Number of Conditioned Zones.* The number of conditioned zones modeled in the computer run.
- *Total Conditioned Volume.* The total volume of conditioned space within the building.

- *Conditioned Slab Floor Area.* The total area of slab floor (on grade or raised) with conditioned space above and the ground or unconditioned space below. This is used to determine the standard design mass requirement for buildings and the default values of the thermal mass requirements for the proposed design.
- *Total Conditioned Floor Area.* The total floor area of conditioned space in the building to be permitted. This area shall be no less than the *Conditioned Slab Floor Area* specified above. The conditioned nonslab floor area is the difference between the *Total Conditioned Floor Area* and the *Conditioned Slab Floor Area* and is used to determine the thermal mass for the Standard Design, the default value of thermal mass for the Standard Design, and the threshold thermal mass requirement for thermal mass credit in the Proposed Design. The conditioned nonslab floor area includes any nonslab floors, raised or not, and raised slab floors with conditioned space above and below the floor.

2.2.4 Building Zone Information

For most compliance documentation, only one row will be reported in this table. Additional rows are reported when a proposed building is modeled as two zones or when attached, unconditioned spaces are modeled, such as crawl spaces or sunspaces.

BUILDING ZONE INFORMATION

Zone Name	Floor Area ft^2)	Volume (ft^3)	# of Units	Zone Type	Tstat Type	Vent Height (ft)	Vent Area (ft^2)
House	1384	11072	1	Conditioned	Setback	2.0	32

- *Zone Name.* Each zone is given a name that is used to categorize information in the following tables.
- *Floor Area (ft^2).* The floor area of the zone measured to outside wall. The sum of the floor area of all conditioned zones shall equal the conditioned floor area reported under "General Information".
- *Volume (ft^3).* The volume of the zone. The sum of the volume of all conditioned zones shall equal the total volume reported under "General Information".
- *# of Units.* The number of dwelling units in the zone. This number may be a fraction for cases of addition alone or a building in which there are more zones than dwellings.
- *Zone Type.* This description controls some modeling restrictions, such as infiltration, internal and solar gains, etc. Possible conditioned zone entries are Conditioned, Living and Sleeping. Possible unconditioned zone entries include Unconditioned, CVCrawl and Sunspace.
- *Thermostat Type*. Possible conditioned zone entries are Setback, NoSetback, LivingStat, SleepingStat. Additional thermostat types may be allowed for optional modeling capabilities.
- *Vent Height (ft).* The height difference between the "inlet" ventilation area and the "outlet" ventilation area. The default ventilation height is determined by the number of stories: one story - 2 feet, two or more stories - 8 feet. Different vent heights may be modeled but a non-default vent height is considered a special feature or special modeling assumption that shall be reported in the *Special Features and Modeling Assumptions* listing for special verification. The ventilation height for other windows is the average height difference between the centers of the lower operable window openings and the centers of the upper operable window openings.
- *Vent Area (ft^2)*. This entry is either the default vent area which is assumed by the ACM based on entries in the Fenestration Surfaces table or some other value entered by the user. A Vent Area value greater than 10% of the total rough-out opening area (all windows treated as opening type: “slider”) of all fenestration shall be reported in the *Special Features and Modeling Assumptions* listing for special verification.

2.2.5 Opaque Surfaces

A row shall be reported in this table for each unique opaque surface in the proposed building. Opaque surfaces include walls, roofs, and floors. Low-rise residential buildings may have either *Standard* or *Improved* envelope construction quality. This is a feature at the whole building level and not at the surface or construction type level. Envelope construction quality is reported in the *Field Verification and Diagnostic Testing* section of the CF-1R.

For buildings that are modeled as multiple thermal zones, the opaque surfaces shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". Alternatively, an additional column may be added to the table to indicate the zone the building element is next to. The zone name used in the header should be the same as the name used in the table titled "Building Zone Information".

OPAQUE SURFACES

Surface Type	Area (ft^2)	U-factor	Cavity Insul R-value	Sheath. Insul. R-value	True Azimuth	Tilt	Solar Gains	Appendix IV Reference	Location/ Comments
Zone=Living									
Wall	105.4	0.088	R-13	na	0	90	Yes	IV1-A3	Typical
Wall	145.4	0.068	R-11	R-4	180	90	Yes	IV1-A3	Typical
Base WallA	100	0.124	na	R-6	0	90	No	IV5-E5	0-2 ft below grade
Base Wall B	160	0.124	na	R-6	0	90	No	IV5-E5	2-6 ft. below grade
Wall	176.8	0.088	R-13	na	270	90	Yes	IV1-A3	Typical
Roof	692	0.031	R-30	na	0	0	Yes	IV4-A8	Typical
Zone=Sleep									
Wall	145.4	0.088	R-13	na	0	90	Yes	IV1-A3	Typical
Wall	176.8	0.068	R-11	R-4	90	90	Yes	IV1-A3	Typical
Wall	145.4	0.088	R-13	na	180	90	Yes	IV1-A3	Typical
Roof	692	0.031	R-30	na	0	0	Yes	IV4-A8	Typical
Zone=SunSpc									
Wall	72	0.088	R-13	na	90	90	Yes	IV1-A3	Sunspace Wall
Wall	90	0.088	R-13	na	180	90	Yes	IV1-A3	Sunspace Wall
Wall	72	0.088	R-13	na	270	90	Yes	IV1-A3	Sunspace Wall
Roof	135	0.031	R-30	na	0	0	Yes	IV4-A8	Sunspace Roof

- *Surface Type.* Valid types are Wall, BaseWallA (0-1.99 ft below grade), BaseWallB (2.0-5.99 ft below grade), BaseWallC (more than 6 ft below grade), Roof/Ceiling, and Floor. If floor is over a crawl space (FlrCrawl), then the U-factors used in the custom budget run are based on having a crawl space. Otherwise, they are not. Floor types and areas are also used to determine the default thermal mass for the Proposed Design and the thermal mass for the Standard Design.
- *Area (ft^2).* The area of the surface.
- *Assembly U-factor.* The overall U-factor of the construction assembly selected from ACM Joint Appendix IV. Note that the U-factors reported in this table are the same whether or not construction quality procedures are followed. There is a credit for construction quality, but it is embedded in the software and not reported as adjustment to the U-factor.
- *Cavity Insul R-val.* The rated R-value of the installed insulation in the cavity between framing members. This does not include framing effects or the R-value of drywall, air films, etc. When insulating sheathing is installed over a framed wall, the "Cavity Insul R-val" should report the insulation in the cavity only. This value is not entered by the user, but is determined when the user selects a standard construction from ACM Joint Appendix IV.

- *Sheath Insul R-val.* The sum total rated R-value of all installed layers of insulating sheathing shall be reported. The sum of the R-values is reported for multiple sheathing layers. This value is not entered by the user, but is determined when the user selects a standard construction from ACM Joint Appendix IV.
- *True Azimuth.* The actual azimuth of the surface after adjustments for building rotation. There are various ways of describing the orientation or azimuth of surfaces. For ACMs approved by the CEC, a standard convention shall be used. The azimuth is zero degrees for surfaces that face exactly north. From this reference the azimuth is measured in a clockwise direction. East is 90 degrees, south 180 degrees and west 270 degrees.
- *Tilt.* The tilt of the surface. Vertical walls are 90°; flat roofs are 0°; floors are 180°.
- *Solar Gains.* A yes/no response is given to indicate if a surface receives solar gains. Surfaces that do not receive solar gains may include floors over crawl spaces and walls adjacent to garages. Only a yes/no response is required since the surface absorptance is a fixed input.
- *ACM Joint Appendix IV Reference.* A reference to the construction assembly selected from ACM Joint Appendix IV. This name may also be referenced from the thermal mass table to indicate an exterior mass wall.
- *Location/Comments.* User provided text describing where the surface is located or other relevant information.

2.2.6 Perimeter Losses

This table provides details about components of the building envelope that are modeled as perimeter losses. Typical perimeter losses are slab edge losses, retaining wall losses, and losses from the base of controlled ventilation crawl spaces. A row is provided in the table for each unique perimeter element. Note that a single F-factor is reported for slab edge losses for slab floor interiors that are carpeted or exposed based on a fixed assumption of 20% of the edge adjacent to exposed slab. This assumption shall be used and separate F-factor values for different interior covering conditions may not be reported or modeled by an approved ACM.

For buildings that are modeled as multiple thermal zones, the items shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". Alternatively, an additional column may be added to the table to indicate the zone the building element is next to. The zone name used in the header should be the same as the name used in the table titled "Building Zone Information."

PERIMETER LOSSES

Perimeter Type	Length (ft)	F-Factor	Insul R-val	Insul Depth (in)	Location/Comments
Zone=Living					
SlabEdge	76	0.70	R-5	24	Exposed edge
Zone=Sleep					
SlabEdge	76	0.70	R-5	24	Exposed edge
Zone=SunSpc					
SlabEdge	65	0.73	R-0	na	Exposed edge

- *Perimeter Type.* The perimeter type. Possible types are slab edge, crawl space perimeter, etc. Names may be abbreviated.
- *Length (ft).* The perimeter length in feet.
- *F-Factor.* The perimeter heat loss factor (see Section 3.2.6).
- *Insul R-Val.* The R-value of the installed insulation. "R-0" or "None" should be reported when no insulation is installed.
- *Insul Depth (in).* The depth that the insulation extends below the top surface of the slab in inches.

- *Location/Comments.* User provided information on the location of the perimeter element or other relevant information.

2.2.7 Fenestration and Doors

The term "fenestration" is used to refer to an assembly of components consisting of frame and glass or glazing materials. According to the standards (Section 101), fenestration includes “any transparent or translucent material plus frame, mullions, and dividers, in the envelope of a building.” Fenestration surfaces include windows, skylights and glazing in doors or other transparent or translucent surfaces. Opaque doors are also included in this section since they represent “openings” in the gross wall or roof, just like window or skylights. This listing reports information about each fenestration product or door. One row is to be included in the listing for each unique condition. When compliance is for all orientations, the building facade orientations shall be reported for the case with the “front” facing north or the orientation shall be reported as “*Any*”.

This listing shall include information about each fenestration surface in the proposed building. Fenestration surfaces include windows, skylights and glazing in doors or other transparent or translucent surfaces. One row is included in the listing for each unique fenestration condition. ACMs shall restrict users to select from a limited list of exterior shading devices and their associated solar heat gain coefficients (SHGCs), namely, those devices and SHGCs listed in the table below for exterior shading devices. ACMs shall not allow users to enter custom shading devices nor account for differences in alternative color, density, or light transmission characteristics. ACMs are required to calculate, but not report, $SHGC_{open}$ and $SHGC_{closed}$ using 2005 Standards calculation procedures and assumptions.

For buildings that are modeled as multiple thermal zones, the fenestration surfaces shall be grouped for each zone and indicated with a header "Zone = <Zone Name>". Alternatively, an additional column may be added to the table to indicate the zone the building element is next to. The zone name used in the header should be the same as the name used in the table titled "Building Zone Information"

FENESTRATION AND DOORS

Fenestration #/Type/Orien	Area (ft^2)	U-factor	Fenes.SHGC	True Az	Tilt	Exterior Shade Type /SHGC	Location / Comments
Zone=Living							
1 Wdw Front(N)	70.4	0.65	0.88	0	90		
2 Wdw Left(E)	70.4	0.65	0.88	90	90	WveScrn/ 0.39	
3 Front Door	20						
4.Garage Door	20						
Zone=Sleeping							
4 Wdw Back(S)	70.4	0.65	0.88	180	90		
5 Wdw Right(W)	70.4	0.65	0.88	270	90	LvrScrn/ 0.36	

- *Fenestration #/Type/Orien.* The # is a unique number for each different fenestration surface entry. The type is Wdw (window) Dr (door) or Sky (skylight). The *Orien* (orientation) is the side of the building (front, left, right or back) followed by the nearest 45° compass point in parenthesis (N, NE, etc.). When compliance is for all orientations, only the side of the building may be reported (front, right, etc.)
- *Area (ft^2).* The area of the surface in square feet. This should generally be the rough frame opening.
- *U-factor*. The rated U-factor of the fenestration product, in Btu/h-ft^2-°F.
- *True Azimuth.* The true (or actual) azimuth of the glazed surface after adjustment for building rotation. The convention for describing the azimuth is standardized as discussed above under opaque surfaces.
- *Tilt.* The tilt of the glazed surface. Most windows will have a 90° tilt. Skylights typically have a tilt equal to the corresponding roof surface.

- *Fenestration SHGC:* The solar heat gain coefficient of the fenestration.
- *Exterior Shade Type/SHGC*. The type of exterior shading device and its solar heat gain coefficient from Table R3-7. "*Standard/0.76*" or " " shall appear when no special exterior shading device is included in the building plans. *Standard (partial bugscreen)* shading shall automatically be given for all window area without other forms of exterior shading devices. This shading assumes that a portion of the window area is covered by bugscreens. Other valid exterior shades include louvered screens (*LvrScrn*), woven sunscreen (*WvnScrn*), and Low Sun Angle Sunscreen (*LSASnScrn*). When used for compliance purposes, ACMs shall not allow or accept input for user-defined exterior shades.

2.2.8 Solar Gain Targeting

This table is only used for special cases, such as sunspaces (an optional modeling capability, and hence a Special Feature). Solar gains that enter conditioned spaces shall be targeted to the air, but when glazing surfaces enclose unconditioned spaces, such as sunspaces, the user is allowed to target all but 25% of the solar gains from these surfaces to mass elements located within the unconditioned space. More than one row of targeting data may be included for each glazed surface. Unassigned solar gain is targeted to the air in the unconditioned space. At least 25% of the solar gain from any sunspace fenestration surface shall be targeted to high surface area lightweight mass or the air. At most 60% of the solar gain may be targeted to the slab floor of a sunspace, especially in the summer. An ACM shall automatically enforce these limits and inform the user of any attempt to exceed these limits.

Note that the use of any optional capability such as sunspace modeling shall be reported in the *Special Features and Modeling Assumptions* listings. In addition, solar gain targeting shall be separately reported in the *Special Features and Modeling Assumptions* listings so that the local enforcement agency can verify that these inputs are reasonable.

SOLAR GAIN TARGETING

Fenestration #/Type/Orien	Mass Name	Winter Fraction	Summer Fraction
1 Wdw Front(N)	SSSlb	0.30	0.30

- *Fenestration #/Type/Orien.* The fenestration surface which transmits solar gain to an interior unconditioned space thermal mass. This corresponds to an item in the fenestration surfaces table.
- *Mass Name.* The name of the mass element to which solar gains are directed. The mass name corresponds to an item in the thermal mass table.
- *Winter Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a heating mode.
- *Summer Fraction.* The fraction of solar gains targeted from the glazing surface to the absorbing thermal mass when the building is in a cooling mode.

2.2.9 Overhangs

Overhangs are a minimum ACM capability and are described in this table.

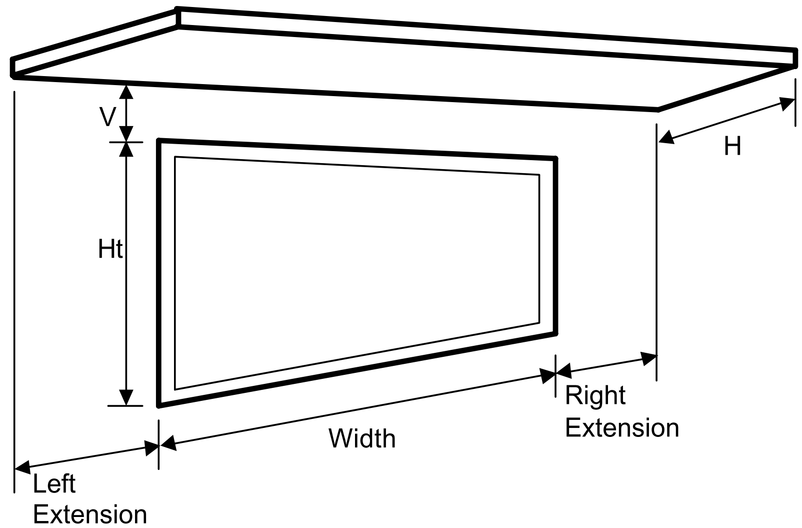

Figure R2-1 – Overhang Dimensions

OVERHANGS

Fenestration			Overhang			
#/Type/Orien	Wdth	Ht	Lngth "H"	Ht "V"	Left Extension	Right Extension
3 Wdw Back(S)	4.0	5.0	2.6	1.5	6.0	6.0

- *Fenestration #/Type/Orien.* This corresponds to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out frame opening for the fenestration (in feet) measured from the edge of the opening on one side to the edge of the opening on the other side.
- *Fenestration Ht.* The height of the rough-out frame opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.
- *Overhang Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the overhang.
- *Overhang Ht "V".* The vertical distance (in feet) from the top of the glazing frame to the bottom edge of the overhang at the distance “H” from the glazing surface. See Figure R2-1.
- *Overhang Left Extension.* The distance in feet from the left edge of the glazing frame to the left edge of the overhang. "Left" and "right" are established from an exterior view of the window.
- *Overhang Right Extension.* The distance in feet from the right edge of the glazing frame to the right edge of the overhang.

2.2.10 Side Fins

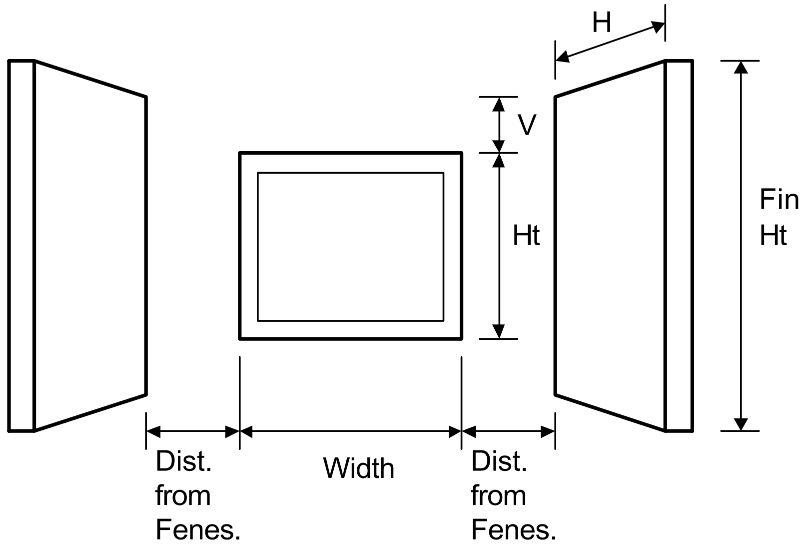

Figure R2-2 – Side Fin Dimensions

SIDE FINS

Fenestration			Left Fin				Right Fin			
#/Type/Orien	Wdth	Ht	Dist from fenes	Lngth "H"	Ht "V"	Fin Ht	Dist from fenes	Lngth "H"	Ht "V"	Fin Ht
3 Wdw Back(S)	4.0	5.0	6.0	2.0	6.0	8.0	6.0	2.0	6.0	8.0

- *Fenestration #/Type/Orien.* This shall correspond to an item in the fenestration surfaces list.
- *Fenestration Wdth.* The width of the rough-out opening for the fenestration (in feet) measured from the edge of the opening or frame on one side to the edge of the opening or frame on the other side.
- *Fenestration Ht.* The height of the rough-out opening for the fenestration (in feet) measured from the bottom of the opening or frame to the top of the opening or frame.
- *Left Fin Dist from fenes*. The distance in feet from the nearest glazing frame edge to the fin. "Left" and "right" are established from an exterior view of the window.
- *Left Fin Lngth "H".* The horizontal distance in feet from the surface of the glazing to the outside edge of the fin.
- *Left Fin Ht "V"*. The vertical distance (in feet) from the top of the glazing frame to the top edge of the fin.
- *Left Fin, Fin Ht.* The height of the fin, in feet.
- *Right Fin.* Similar to Left Fin items.

2.2.11 Inter-Zone Surfaces

This listing is used only for proposed designs modeled as multiple thermal zones which is considered an exceptional condition and shall also be listed in the *Special Features and Modeling Assumptions* listings for the CF-1R. The *Special Features and Modeling Assumptions* listing shall direct plan and field checkers to the listings for *Interzone Surfaces* and *Interzone Ventilation*. The *Interzone Surfaces* listing describes the characteristics of the surfaces that separate the zones.

For buildings that are modeled with more than two thermal zones, the inter-zone surfaces shall be grouped so that it is clear which zones are separated by the surfaces. The groupings shall be labeled "Between ZoneName1 and ZoneName2" or some similar convention. This information may also be provided through additional columns in the table.

INTER-ZONE SURFACES

Surface Type	Area (ft^2)	U-factor	Cavity Insul R-val	Sheath Insul R-valu	ACM Joint Appendix IV	Location/Comments
Between Living and Sunspc						
Wall	100	0.09	R-11	na	Wall-2	Insulated partition
Glass	30	1.10	SglGls	na		Sliding glass door
Between Sleeping and Sunspc						
Wall	220	0.09	R-11	R-4	Wall-2	Insulated partition
Glass	10	1.10	SglGls	na		Window
Between Living and Sleeping						
Wall	206	0.293	R-0	na	Wall-3	Gypsum partitions
Door	40	0.33	R-0	na		Hollow core doors

- *Surface Type.* The type of surface separating the zones. Possible types are window, wall, etc.
- *Area (ft^2).* The area of the surface in square feet that separates the zones.
- *U-val.* The U-factor of the surface.
- *Cavity Insul R-val.* The R-value of insulation installed in cavity of the framed construction assembly. This does not account for framing effects, drywall, air films, etc.
- *Sheath Insul R-val.* The total R-value of all insulation layers (layers R-2 or greater) not penetrated by framing. Excludes low R-value layers such as sheetrock, building paper, and air films.
- *ACM Joint Appendix IV Reference*. A reference to a selection from ACM Joint Appendix IV.
- *Location/Comments.* User provided information on the location of the inter-zone surface or other relevant information.

2.2.12 Inter-Zone Ventilation

This listing is used for proposed designs that are modeled as multiple building zones. The modeling of multiple building zones is considered an exceptional condition that shall be reported in the *Special Features* and *Modeling Assumptions* listings, which shall also refer to the information in this listing when this listing is generated by the ACM to echo user inputs for Inter-Zone Ventilation. If inter-zone ventilation is modeled, it shall be reported in this listing. It describes natural and/or mechanical ventilation systems that separate the zones.

For buildings that are modeled with more than two thermal zones, the inter-zone ventilation items shall be grouped so that it is clear which zones are linked by the items. The groupings shall be labeled "Between ZoneName1 and ZoneName2" or some similar convention. This information may also be provided through additional columns in the table.

INTER-ZONE VENTILATION

Vent Type	Inlet Area	Outlet Area	Height Diff.	Fan Watts	Fan Flow (cfm)	Location/ Comments
Between Living and Sunspc						
Natural	20	20	3	na	na	

- *Vent Type.* Possible types are natural and fan.
- *Inlet Area.* The area of the air inlet in square feet. This is used only when vent type is "natural".
- *Outlet Area.* The area of the air outlet in square feet. This is used only when vent type is "natural".
- *Height Diff.* The elevation difference between the inlet and the outlet in feet. This is used only when vent type is "natural". Default is two feet.
- *Fan Watts.* The fan power rating in watts. This is used only for sunspaces and only then when vent type is "fan". Fan energy may be reported as a separate line item or added to the TDV energy for heating.
- *Fan Flow (cfm).* The cubic feet per minute of air flow provided when the fan is operating. This is used only for sunspaces and then only when vent type is "fan".
- *Location/Comments*. User provided text describing where the item is located or other relevant information.

2.2.13 Infiltration/Ventilation

This listing is only produced when the applicant has used reduced infiltration measures (and mechanical ventilation when necessary) to improve the overall energy efficiency of the Proposed Design while maintaining adequate air quality. Reduced infiltration credit may be taken for duct sealing and installation of an air retarder without a blower door test. Otherwise, the use of reduced infiltration requires diagnostic blowerdoor testing by a installer and a certified HERS rater to verify the modeled reduced leakage area and to ensure minimum infiltration/ventilation rates are achieved. Relevant information regarding infiltration and ventilation shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R. The listings shall indicate that diagnostic blower door testing shall be performed as specified in ASTM E 779-03, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*. This listings shall also report the target $CFM50_H$ required for the blower door test to achieve the modeled SLA and the minimum $CFM50_H$ (corresponding to an SLA of 1.5) allowed to avoid backdraft problems. This minimum allowed value is considered by the Commission to be “unusually tight” in the requirements of the California Mechanical Code.

When the target $CFM50_H$ of the *Proposed Design* is below the value corresponding to an SLA of 3.0, mechanical ventilation with a minimum capacity of 0.047 CFM per square foot of conditioned floor area is required. This requirement for mechanical ventilation and minimum capacity shall be reported in the *Field Verification and Diagnostic Testing* listings of the CF-1R. Also, the *Field Verification and Diagnostic Testing* listings shall state that when the measured $CFM50_H$ is less than the minimum allowed value, corrective action shall be taken to either intentionally increase the infiltration or provide for mechanical supply ventilation adequate to maintain the dwelling unit at a pressure greater than -5 pascals relative to the outside average air pressure with other continuous ventilation fans operating.

When mechanical ventilation is part of the Proposed Design the exhaust and supply fan wattages shall be reported in this listing and the *Field Verification and Diagnostic Testing* listings. Whenever mechanical ventilation is modeled by the user or required by modeling an SLA of 3.0 or less, the mechanical ventilation capacity selected by the user shall be greater than or equal to 0.047 cfm per square foot of conditioned floor area to be modeled by an approved ACM. If the user enters a volumetric capacity that is less than 0.047 cfm/ft^2, the ACM shall indicate an input error to the user and block compliance output.

When reduced infiltration or mechanical ventilation is modeled, the *Special Features and Modeling Assumptions* listings shall include a statement that the homeowner’s manual provided by the builder to the homeowner shall include instructions that describe how to use the operable windows or mechanical ventilation to provide for proper ventilation.

INFILTRATION/VENTILATION DETAILS *(Example Listing)*

Blower Door Leakage Target ($CFM50_H$/SLA)	Blower Door Leakage Minimum ($CFM50_H$/SLA)	Vent. Fan CFM (Supply/Exhaust)	Mechanical Vent Fans (Watts) [Supply/Exhaust]
1250/2.9	586/1.5	200/300	*50/75*

- *Blower Door Leakage Target ($CFM50_H$/SLA):* The measured blower door leakage in cfm at 50 pascals of pressurization and its equivalent Specific Leakage Area (SLA) value.
- *Blower Door Leakage Minimum ($CFM50_H$/SLA):* The limit for the blower door leakage test to avoid backdrafting, which corresponds to a Specific Leakage Area (SLA) of 1.5, considered to be "unusually tight" for California Mechanical Code compliance. The ACM shall report in the *Field Verification and Diagnostic Testing* listings that the Commission considers this minimum CFM and the corresponding SLA of 1.5 or less to be "unusually tight" per the Uniform Mechanical Code. In the sample listing given above a 1600 square foot house and the SLA lower limit of 1.5 is used to determine the *Blower Door Leakage Minimum* shown.
- *Vent. (Ventilation) Fans (CFM):[Supply/Exhaust]* The total volumetric capacity of supply fans and exhaust fans listed separately, separated by a slash (or reported in separate columns). The balanced portion of mechanical ventilation is the smaller of these two numbers while the unbalanced portion is the difference between these two numbers. These values are reported in cubic feet per minute.
- *Mechanical Vent. (Ventilation) Fans (Watts) [Supply/Exhaust]:* The total power consumption of the supply ventilation fans and the total power consumption of the exhaust ventilation fans in watts.

Use of an air retarding wrap shall be reported in the Special Features and Diagnostic Testing listings.

2.2.14 Slab Surfaces

This table shall be listed when the building has slab surfaces but does not qualify as a high mass design (see Thermal Mass in Chapters 3 and 4). If the building qualifies as a high mass design, this listing is omitted and the listing for high mass designs is included.

SLAB SURFACES

Mass Name	Area (ft^2)
Zone=Living	
Standard Slab	1600

- *Mass Name.* The name of the mass element.
- *Area (ft^2).* The area of the mass in square feet.

2.2.15 Thermal Mass for High Mass Design

This table can only appear if and when the Proposed Design qualifies as a high mass building (see Chapter 3). High mass buildings are considered to be an exceptional condition and shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R. The table specified below provides detail about the thermal mass elements in qualifying high mass building. One row is provided in the table for each mass element.

Thermal mass elements may be located within a single zone, they may separate zones or they may be located on an exterior wall. Mass elements in each of these categories shall be grouped and labeled accordingly. Additional columns may be added to the table to provide this information.

THERMAL MASS FOR HIGH MASS DESIGN

Mass Name	Area (ft^2)	Thickness (inches)	Volumetric Heat Capacity (Btu/ft^3-°F)	Conductivity (Btu-in)/(hr-ft^2-°F)	ACM Joint Appendix IV	Inside Surface R-value (hr-ft^2-°F)/Btu	Location/Comments
Zone=Living							
ExpSlb-L	273	3.5	28	.98	na	0	Exposed in living
CarSlb-L	419	3.5	28	.98	na	2	Carpeted in living
Zone=Sleep							
ExpSlb-S	273	3.5	28	.98	na	0	Exposed in sleeping
CarSlb-S	419	3.5	28	.98	na	2	Carpeted in sleeping
Zone=SunSpc							
SSSlb	450	3.5	28	.98	na	0	Sunspace slab
Between Sunspc and Living							
SSWall	100	8.0	28	.98	na	0	Masonry wall

- *Mass Name.* The name of the mass element. This name may be referenced from the optional solar gains targeting section of the fenestration surfaces table.
- *Area (ft^2).* The area of the mass in square feet.
- *Thickness.* The mass thickness in inches.
- *Heat Capacity.* The volumetric heat capacity of the mass material in Btu/ºF-ft^3.
- *Conductivity.* The conductivity of the mass material in Btu-in/h-ft^2-°F.
- *ACM Joint Appendix IV Reference.* A reference to a lookup from ACM Joint Appendix IV..
- *Inside Surface R-value.* The thermal resistance of any material (such as carpet or tapestry) that may exist on the inside surface of the thermal mass excluding air films. For instance, if a mass element is carpeted, a surface R-value of 2 is the fixed input. For mass elements that separate thermal zones, the surface R-value may be reported separately for each side of the mass.
- *Location/Comments.* User provided information on the location of the mass element or other relevant information.

2.2.16 HVAC Systems

Information is provided on the type of heating and cooling systems proposed for each zone of the building. Data in the table is organized to accommodate any type of heating or cooling system so some of the information is not applicable for all system types. When the information is not applicable, "na" is reported. Data in this table should be organized first by thermal zones and then by heating and cooling systems. Note that the thermostat type is reported under "Building Zone Information" described above.

For buildings that are modeled as multiple thermal zones, the items shall be grouped for each zone and indicated with a header "Zone = <ZoneName>". The zone name used in the header should be the same as the name used in the table titled "Building Zone Information"

HVAC SYSTEMS

Equipment Type	Minimum Equipment Efficiency (or Water Heating System Name)	Verified Refrigerant Charge	Verified Adequate Airflow	Verified Fan Watt Draw	Verified Cooling Capacity
Zone=Living					
Furnace	0.78 AFUE	N/A	N/A	N/A	N/A
AirCond-Split	10.0 SEER/9.3 EER	Yes	Yes	240	Yes
Zone=Sleep					
CombHydro	Upper Floors	N/A	N/A	N/A	N/A
AirCond-Split	10.0 SEER	No	No	No	No

- *Equipment Type*. The type of heating or cooling equipment. This is specified separate from the distribution type. Required heating equipment and cooling equipment entries are listed in Table R2-1 and Table R2-2. When the proposed house is not air conditioned, the entry should be NoCooling. If more than one type of equipment is specified, they may be listed on subsequent rows. If Gas Absorption equipment is specified, it shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R forms printed by the ACM.
- *Minimum Equipment Efficiency.* The minimum equipment efficiency needed for compliance. The applicable efficiency units should also be reported, for instance AFUE for furnaces and boilers, HSPF for electric heating equipment, and SEER for heat pumps (cooling) and central air conditioners. In the case of combined hydronic heating, the name of the water heating system shall be identified. If the equipment type is Electric (other than heat pump), an HSPF of 3.413 should be entered, except for radiant systems which use a maximum HSPF of 3.55. EER indicates that the energy efficiency ratio at ARI test conditions has been specified and will be verified according to the procedure in ACM Appendix RI - Procedures for Verifying the Presence of a Thermostatic Expansion Valve or High Energy Efficiency Ratio Equipment, and shall also be reported in the *Field Verification and Diagnostic Testing* listings.
- *Verified Refrigerant Charge.* The choices are 'Yes' or 'No' where 'Yes' means that either refrigerant charge is verified or a TXV is installed and verified. Refrigerant charge credit is applicable to split system air conditioners and heat pumps only. The two equipment types that can comply by verifying refrigerant charge are SplitAirCond, and SplitHeatPump.
- *Verified Adequate Airflow.* Yes indicates that the air flow will be tested and verified according to the procedure in ACM Appendix RE - Forced Air System Fan Flow and Air Handler Fan Watt Draw and shall also be reported in the *Field Verification and Diagnostic Testing* listings. No indicates that the default air flow is used.
- *Verified Fan Energy*. A number such as 240 indicates the user specified air handler fan watt draw that will be tested and verified according to the procedure in ACM Appendix RE - Forced Air System Fan Flow and Air Handler Fan Watt Draw and shall also be reported in the *Field Verification and Diagnostic Testing* listings No indicates that the default fan watt draw is used.
- *Verified Maximum Cooling Capacity.* Yes indicates that the proposed design will have an air conditioner sized according to the ACM calculations in ACM Appendix RF – HVAC Sizing and this shall also be reported in the *Field Verification and Diagnostic Testing* listings. Systems may claim this credit only if they also have claimed credit for the combination of verified adequate airflow, sealed and tested new duct systems, and proper refrigerant charge (or alternatively a TXV). No indicates that no sizing credit is being taken.

Table R2-1 – HVAC Heating Equipment Descriptors

Recommended Descriptor	Heating Equipment Reference
CntrlFurnace	Gas- or oil-fired central furnaces, propane furnaces or heating equipment considered equivalent to a gas-fired central furnace, such as wood stoves that qualify for the wood heat exceptional method. Gas fan-type central furnaces have a minimum AFUE=78%. Distribution can be gravity flow or use any of the ducted systems. [Efficiency Metric: AFUE]
Heater	Non-central gas- or oil-fired space heaters, such as wall heaters floor heaters or unit heater. Equipment has varying efficiency requirements. Distribution is ductless and may be gravity flow or fan-forced.. Can refer to floor furnaces and wall heaters within the description field for CntrlFurnaces, [Efficiency Metric: AFE]
Boiler	Gas or oil boilers. Distribution systems can be Radiant, Baseboard or any of the ducted systems. Boiler may be specified for dedicated hydronic systems. Systems in which the boiler provides space heating and fires an indirect gas water heater (IndGas) may be listed as Boiler/CombHydro Boiler and shall be listed under “Equipment Type” in the HVAC Systems listing. [Efficiency Metric: AFUE]
SplitHeatPump	Heating side of central split system heat pump heating systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: HSPF]
PkgHeatPump	Heating side of central packaged heat pump systems. Central packaged heat pumps are heat pumps in which the blower, coils and compressor are contained in a single package, powered by single phase electric current, air cooled, rated below 65,000 Btuh. Distribution system shall be one of the ducted systems. [Efficiency Metric: HSPF]
LrgPkgHeatPump	Heating side of large packaged units rated at or above 65,000 Btu/hr (heating mode). Distribution system shall be one of the ducted systems. These include water source and ground source heat pumps. [Efficiency Metric: COP]
RoomHeatPump	Heating side of non-central room air conditioning systems. These include small ductless split system heat pump units and packaged terminal (commonly called “through-the-wall”) units. Distribution system shall be DuctIndoor. [Efficiency Metric: COP]
Electric	All electric heating systems other than space conditioning heat pumps. Included are electric resistance heaters, electric boilers and storage water heat pumps (air-water) (StoHP). Distribution system can be Radiant, Baseboard or any of the ducted systems. [Efficiency Metric: HSPF]
CombHydro	Water heating system can be storage gas (StoGas, LgStoGas), storage electric (StoElec) or heat pump water heaters (StoHP). Distribution systems can be Radiant, Baseboard, or any of the ducted systems and can be used with any of the terminal units (FanCoil, RadiantFlr, Baseboard, and FanConv).

Table R2-2 – HVAC Cooling Equipment Descriptors

Recommended Descriptor	Cooling Equipment Reference
NoCooling	Entered when the proposed building is not air conditioned or when cooling is optional (to be installed at some future date). Both the Standard Design equivalent building and the proposed design use the same default system (refer to sections 3.6.2). [Efficiency Metric: SEER]
SplitAirCond	Split air conditioning systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER]
PkgAirCond	Central packaged air conditioning systems less than 65,000 Btuh cooling capacity. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER]
LrgPkgAirCond	Large packaged air conditioning systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system shall be one of the ducted systems. [Efficiency Metric: EER]
RoomAirCond	Non-central room air conditioning cooling systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called through-the-wall) air conditioning units. Distribution system shall be DuctIndoor. [Efficiency Metric: EER]
SplitHeatPump	Cooling side of split heat pump systems. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER and EER<65,000 Btu/hr EER>65,000 Btu/hr]
PkgHeatPump	Cooling side of central single-packaged heat pump systems with a cooling capacity less than 65,000 Btuh. Distribution system shall be one of the ducted systems. [Efficiency Metric: SEER]
LrgPkgHeatPump	Cooling side of large packaged heat pump systems rated at or above 65,000 Btu/hr (cooling capacity). Distribution system shall be one of the ducted systems. [Efficiency Metric: EER]
GasCooling	Gas absorption cooling. Three descriptors, COP95, the rated COP for the gas portion, CAP95, the rated capacity, and PPC, the parasitic electric energy at rated conditions in Watts.
RoomHeatPump	Cooling side of non-central, room heat pump systems. These include small ductless split-system air conditioning units and packaged terminal (commonly called "through-the-wall") units. Distribution system shall be DuctIndoor. [Efficiency Metric: EER]
EvapDirect	Direct evaporative cooling systems. The SEER is set to 11.0. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. [Efficiency Metric: SEER]
EvapIndirDirect	Indirect-direct evaporative cooling systems. The SEER is set to 13.0. The default distribution system location is DuctAttic; evaporative cooler duct insulation requirements are the same as those for air conditioner ducts. [Efficiency Metric: SEER]

Table R2-3 – HVAC Distribution Type and Location Descriptors

Recommended Descriptors	HVAC Distribution Type and Location Reference
Air Distribution Systems	Fan-powered, ducted distribution systems that can be used with most heating or cooling systems. When ducted systems are used with furnaces, boilers, or combined hydronic/water heating systems the electricity used by the fan shall be calculated using the methods described later in this manual. R-value shall be specified in "Duct R-value" column when a ducted system is specified
DuctsAttic	Ducts located overhead in the unconditioned attic space
DuctsCrawl	Ducts located underfloor in the unconditioned crawl space
DuctsCVC	Ducts located underfloor in a controlled ventilation crawl space
DuctsGarage	Ducts located in an unconditioned garage space.
DuctsBasemt	Ducts located in an unconditioned basement space
DuctsInEx12	Ducts located w ithin the conditioned floor space except for less than 12 lineal feet of duct, typically an HVAC unit in the garage mounted on return box with all other ducts in conditioned space.
DuctsInAll	HVAC unit or systems with all HVAC ducts located within the conditioned floor space. Location of ducts in conditioned space eliminates conduction losses but does not change losses due to leakage. Leakage from either ducts that are not tested for leakage or from sealed ducts are modeled as leakage to outside the conditioned space.
DuctsNone	Air distribution systems without ducts such as ductless split system air conditioners and heat pumps, window air conditioners, through-the-wall heat pumps, etc.
DuctsOutdoor	Ducts located in exposed locations outdoors.
Ductless Systems	Ductless radiant or warm/cold air systems using fan-forced or natural air convection and hydronic systems relying upon circulation pumps and fan-forced or natural air convection, and
Furnaces	Heating equipment such as wall and floor furnaces
Radiant	Radiant electric panels or fanless systems used with a boiler, electric or heat pump water heater, or combined hydronic heating equipment.
Baseboard	Electric baseboards or hydronic baseboard finned-tube natural convection systems

2.2.17 Maximum Cooling Capacity

This listing is always provided, however, the column for maximum cooling capacity is completed only when compliance credit is specified for verified cooling capacity is specified in Section 2.2.16 HVAC Systems. Systems may claim this credit only if they also have claimed credit for the combination of verified adequate airflow, sealed and tested new duct systems, and proper refrigerant charge (or alternatively a TXV). The design loads are calculated in accordance with appendix RF-2005 using the 1.0% Summer Design Dry Bulb and 1.0% Summer Design Wet Bulb outdoor design temperature data from Joint Appendix ACM II and inside design temperatures from Standards Section 150(h). Heating system sizing is not required, but may be included at the ACM vendors option.

HVAC SIZING

Location: Modesto, Cooling design Temp = 99, Cooling Daily Range = 28

Equipment Type	Sensible Design Cooling Load Btu/hr)	Design Cooling Capacity at ARI Rated Conditions Design Equipment Capacity (Btu/hr)	Maximum Cooling Capacity for Verified Cooling Capacity ACM Credit (Btu/hr)
Zone=Living			
AirCond-Split	**19730**	**23470**	**N/A**
Zone=Sleeping Living			
AirCond-Split	9873	11270	N/A
Building Total	29603	34740	40740

- *Equipment Type.* The type of heating or cooling equipment.
- *Sizing Location.* Location for sizing calculation from list in the Joint Appendices ACM II.
- *Cooling Outside Design Temperature* (°F). As defined for the sizing location in the Joint Appendices ACM II.
- *Cooling Outside Daily Range* (°F). As defined for the sizing location in the Joint Appendices ACM II.
- *Inside Design Temperature (*°F). As required in Standards Section 150(h).
- *Sensible Design Cooling Load (Btu/hr).* Total sensible cooling load at design conditions including duct losses. Calculated in accordance with Appendix RF-2005.
- *Design Cooling Capacity at ARI Conditions (Btu/hr).* Rated capacity needed to meet the Sensible Design Cooling Load calculated in accordance with Appendix RF-2005.
- *Maximum Allowable Cooling Capacity for ACM Credit for the building.* Maximum total rated system cooling capacity that may be installed if claiming the sizing credit. For buildings with more than one system the sum fo the sizes of the equipment installed must be less than the total *Allowable Cooling Capacity for ACM Credit for the building*. Calculated in accordance with Appendix RF-2005.

2.2.18 Duct Systems

This listing shall be displayed any time ducts are included in the heating and/or cooling system sealing and testing is specified. As many rows as necessary may be used to describe each duct system.

DUCT SYSTEMS

Equipment Type	Distribution Type and Location	Duct R-value (h-ft²-°F/Btu)	Verified Duct Leakage
Furnace / SplitAirCond	DuctsAttic	4.2	Not Tested
Furnace / SplitAirCond	DuctsAttic	8	Tested New Ducts
Furnace / SplitAirCond	DuctsAttic	4.2	Tested Existing Ducts

- *Equipment Type.* The type of heating or cooling equipment. This is specified separate from the distribution type. Required heating equipment and cooling equipment entries are listed in Table R2-1 and Table R2-2. When the proposed house is not air conditioned, the entry should be NoCooling. If more than one type of equipment is specified, they may be listed on subsequent rows.
- *Duct R-value (hr-ft^2-°F/Btu)*. The nominal R-value of the duct insulation.

- *Distribution Type and Location*. The default distribution type and location is a ducted, central system with 100% of the ducts in the attic. If a duct design is specified with duct locations on the plans but without specific duct surface areas (sizes and lengths) specified, the *Special Features and Modeling Assumptions* listing shall specify the default duct locations. To use DuctsCrawl or DuctsBsmt, all supply registers shall be in the floor or within two feet of the floor and the *Special Features and Modeling Assumptions* listings shall indicate that all supply registers are in the floor or within two feet of the floor. These two cases do not require field verification. All other cases require field verification.
- *Verified Duct Leakage*. If verified (tested) duct leakage is specified by the user, the requirement for diagnostic testing shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R.

2.2.19 Supply Duct System Details

This listing shall be displayed any time credit for ducts in conditioned space, reduced duct surface area, and/or combinations of higher performance insulation (including ducts buried under the attic insulation) are specified. The portions of duct run located on the floor of the attic within 3.5 inches of the ceiling gypsum board and covered or partially covered with blown attic insulation of R-30 or greater in houses meeting the criteria for Insulation Installation Quality (ACM RH) may take credit for increased effective duct insulation. A full description of the requirements and criteria for supply duct system details is in Section 4.8. As many rows as necessary may be used to describe each duct run. These credits shall also be reported in the *Special Features and Modeling Assumptions* listings.

SUPPLY DUCT SYSTEM DETAILS

Description	Location	Duct Length (ft)	Duct Diameter (in.)	Duct Insulation R-value (h-ft²-°F/Btu)	Buried Duct	Attic Insulation R-value (h-ft²-°F/Btu)	Attic Insulation Type
Main 1	Attic	35	16	4.2	No	N/a	N/a
Branch 1	Crawlspace	15	12	4.2	No	N/a	N/a
Branch 2	Conditioned	10	12	4.2	No	N/a	N/a
Run 1	Attic	22	6	4.2	Yes	38	Fiberglass
Run 2	Attic	17	6	4.2	Yes	38	Cellulose
Run 3	Attic	12	6	4.2	Deep	38	Cellulose

Effective Supply System Duct R-value = 5.6

- *Description (text):* Description given to each length of supply duct.
- *Location* (prescribed descriptor): The location of the duct. Permissible types: Listed in Table R2-3.
- *Duct Length (ft).* The length of the duct in feet.
- *Duct Diameter (in.)* The diameter of the duct in inches.
- *Duct Insulation R-value (hr-ft^2-°F/Btu)*. The nominal R-value of the duct insulation.
- *Buried Duct (prescribed descriptor).* The choices are 'Yes', 'No' or 'Deep'. 'No' means that the ducts are not buried and no credit is being taken. 'Yes' means that this duct is located on the floor of the attic within 3.5 inches of the ceiling gypsum board and will be covered or partly covered by blown ceiling insulation. 'Deep' applies when duct segment is deeply buried in lowered areas of ceiling and has at least 3.5" of blown insulation above the top of the duct.
- *Attic Insulation R-value (hr-ft^2-°F/Btu)*. The nominal R-value of the attic insulation covering buried ducts
- *Attic Insulation Type (prescribed descriptor).* The choices are 'Fiberglass' for blown fiberglass or 'Cellulose' for blown cellulose.

2.2.20 Special Systems - Hydronic Distribution Systems and Terminals

This listing shall be completed for hydronic systems that have more than 10 feet of piping (plan view) located in unconditioned space. As many rows as necessary may be used to describe the piping system. Note that hydronic heating systems (combined or not) shall be reported in the *Special Features and Modeling Assumptions* listings. The entry for the *Special Features and Modeling Assumptions* listings shall indicate any additional listings that are reported for this feature so that the local enforcement agency can verify the additional information needed to check this special feature.

SPECIAL SYSTEMS - HYDRONIC DISTRIBUTION SYSTEMS AND TERMINALS

Distribution System Name	Terminal Type	Number (#)	Piping Run Length (ft)	Nominal Pipe Size (in)	Insulation Thickness (in)	Insulation R-value
HydFanCoil	FanCoil	1	15	1.5	1.5	6.0
	Baseboard	1	20	,75	1	4.0
	FanCoil	1	15	.5	1.5	4.0

- *System Name (text):* Description given to the hydronic system.
- *Terminal Type (prescribed descriptor):* The type of terminal equipment used in the system. Permissible types: Listed in Table R2-4.

Table R2-4 – Hydronic Terminal Descriptors

Descriptor	Hydronic Terminal Reference
FanCoil	Ducted fan coil used in central systems
Baseboard	Baseboard convector using natural convection
RadiantFlr	Radiant floor

- *Piping Run Length (ft).* The length (plan view) of distribution pipe located in unconditioned space, in feet, between the primary heating/cooling source and the point of distribution.
- Nominal *Pipe Size.* The nominal (as opposed to true) pipe diameter in inches.
- *Insulation Thickness (in).* The thickness of the insulation in inches. Enter "none" if the pipe is uninsulated.
- *Insulation R-value (hr-ft^2-°F/Btu)*. The installed R-value of the pipe insulation. Minimum pipe insulation for hydronic systems is as specified in Standards Section 150 (j).

2.2.21 Water Heating

Water Heating Systems

This set of listings includes information about water heating systems. A water heating system may serve more than one dwelling unit, or a single dwelling unit may have more than one water heating system. A water heating system may also have more than one water heater, but may have only one distribution system. Each water heating system in the building is defined in one or more rows in the following two tables. Data in these tables is associated with data in the Water Heater/Boiler Equipment Detail Table. When there are multiple water heater types in a system, the last two columns may be repeated as necessary.

When an ACM models a water heating system that does not have a single separate water heater serving each dwelling unit, it shall be reported in the *Special Features and Modeling Assumptions* listings of the CF-1R. The *Special Features and Modeling Assumptions* listing shall cross-reference the listing below whenever multiple water heaters serve one or more dwelling units or when a single water heater serves more than one dwelling unit. Information concerning auxiliary energy systems, the performance and features of instantaneous gas, large storage gas and indirect gas water heaters, and combined hydronic equipment, if installed, shall also be included in the *Special Features and Modeling Assumptions listing* if energy credit is taken for such systems.

WATER HEATING SYSTEMS CREDIT (Multiple systems in single dwelling unit)

System Name	Distribution System in Unit(s)	Recirculation System Control	Water Heater Name	Number of WH in System
System 1	Recirc/Timer	n. a.	State100	1
System 2	Recirc/Timer	n. a.	State50	1
System 3	pOU	n. a.	Loch006	1

WATER HEATING SYSTEMS CREDIT (Systems serving multiple dwelling units)

System Name	Distribution System in Unit(s)	Recirculation System Control	Water Heater Name	Number of WH in System
System 1	Stnd	RTm/Tmp (Stnd)	State100	3
System 2	Stnd	RDmd	State50	4

Notes

- *System Name.* This is a user defined name for the water heating system that provides a link between the water heating systems table, the Water Heating Systems Credits table, and the Water Heater/Boiler Equipment Detail table.
- *Distribution System in Unit(s).* Several specific distribution systems are recognized for distributing water within each dwelling unit. The distribution system listed in this column should be selected from Table R2-5.
- *Recirculation System Control.* This is only used for systems that serve multiple dwelling units. Enter a type of control from Table R2-6.
- *Water Heater Name (text).* This is a user defined name that provides a link between the *Water Heater Systems Credit* table and the *Water Heater/Boiler Equipment Detail* table. This table may be repeated if different types of water heaters are used in the same system.
- *Number of WH in System.* The number of identical water heaters of this type in the system.

Table R2-5 – Water Heating Distribution System (Within Dwelling Units) Descriptors

Distribution System Measure	Code	Description
Pipe Insulation (kitchen lines = 3/4 inches) – Standard Case	STD	Standard (non-recirculating) potable water heating system with tank storage remote from points of consumptive use. The portions of the pipe run from the water heater to the kitchen fixtures that are equal to or greater than 3/4 inch in diameter are insulated, as required by Section 151 (f) 8 D.
Pipe Insulation (all lines)	PIA	All pipes from the water heater to the fixtures are insulated, not just the ones equal to or greater than 3/4 inches to the kitchen, which is required by Section 151 (f) 8 D.
Standard pipes with no insulation	SNI	Standard water heating system with no insulation on pipes equal to or greater than 3/4 inches in diameter to the kitchen.
Point of Use	POU	Point-of-use potable water heating system, within 8' of fixtures
Parallel Piping	PP	A system of individual pipe runs from a manifold at the water heater to each fixture. This is also sometimes called homerun piping.
Recirculation (no control)	RNC	Recirculation system, with no control. The pump runs continuously.
Recirculation + timer control	RTm	Recirculation system, with timer control. The pump operates on a timeclock.
Recirculation + temperature control	RTmp	Recirculation system, with the pump controlled to maintain a minimum temperature in the circulation system.
Recirculation + timer/temperature	RTmTmp	Recirculation system, with combination timer control and temperature control.
Recirculation + demand control	RDmd	Recirculation system, with demand control.

Table R2-6 – Control Systems for Multi-Unit Distribution Systems

Type of Control	Code	Description
Uncontrolled Recirculation	NoCtrl	Circulation pump runs continuously.
Timer Control	STD	Recirculation system, with timer control. The pump operates on a timeclock.

Table R2-7 – Water Heater Types

Recommended Descriptor	Water Heater Reference
StoGas	Gas, propane, or oil-fired storage tank ≥ 2 gal, input ≤ 75,000 Btu/hr
LgStoGas	Gas, propane, or oil-fired storage tank, input > 75,000 Btu/hr
StoElec	electric-resistance-heated storage tank ≥ 2 gal
InstGas	instantaneous gas-fired, storage < 2 gal
InstElec	instantaneous electric-resistance-heated, storage < 2 gal
StoHP	electric heat pump with storage tank
IndGas	storage tank indirectly heated by gas- or oil-fired source
Boiler	boiler dedicated solely to hydronic space heating

Table R2-8 – Pipe Conditions for Systems Serving Multiple Dwelling Units

System Name	**Length of pipes inside the space**	**Insulation of pipe inside the space**	**Length of pipes in ambient air**	**Insulation of pipes in ambient air**	**Length of pipes underground**	**Insulation of pipes underground**
System 1	88	Standard	32	Extra	0	N/a
System 2	96	Standard	16	Standard	0	N/a

Water Heater/Boiler Equipment Detail

This listing provides information about the energy characteristics of the water heaters or boilers used to provide either domestic hot water or space heating through a combined hydronic (*CombHydro*) system. This table may be used for both NAECA and for non-NAECA water heaters (as specified by the Appliance Efficiency Regulations). This listing describes the equipment that serves the water heating system or systems. The information in the table will not be applicable to every water heater type. When the information is not applicable, "na" may be reported.

WATER HEATER/BOILER EQUIPMENT DETAIL

Water Heater Name	**Type**	**Efficiency**	**Efficiency Units**	**Tank Size (gal)**	**Rated Input (kBtuh)**	**Combined Hydronic Pump (watts)**	**Standby Loss (fraction)**	**Tank Total R-value (hr-ft^2-°F/Btu)**	**Pilot Light (Btu/h)**
CombHydState100	Boiler	0.78	AFUE	40	60.00		na	na	na
BigRmWH	LgStoGas	0.79	RE	50	75.00		0.04	15.30	na
Loch006	StoGas	0.78	EF	30	na.		na.	Na.	na.
State100 Hydro	StoGas	0.79	EF	30	40	40	na.	Na.	na.
State50	StoGas	0.80	EF	40	na.		na.	Na.	na.

- *Water Heater Name (text):* Name of water heater specified in the Water Heating Systems listing. In the case of a hydronic system heater, the name shall be unique in order to distinguish it from other water heaters.
- *Water Heater Type (recommended descriptor).* The water heater type will be one of the following choices from Table R2-7. The large storage gas water heaters are larger than the 75,000 Btu/h maximum input rated by the National Appliance Energy Conservation Act (NAECA). Indirect gas water heaters are essentially a boiler with a separate storage tank. Additional data required for large storage gas and indirect gas types is entered later in the Water Heater/Boiler Equipment Detail table. "Gas" is used for propane as well as natural gas. If oil water heaters are used, the "gas" choices may be selected.

- *Efficiency.* The efficiency of the water heater.
- *Efficiency Units.* Enter the units used for efficiency. For NAECA water heaters the energy factor (EF) will be entered. Thermal efficiency is the performance measure for instantaneous gas water heaters (*InstGas*), large storage gas/oil water heaters (*LgStoGas*) and indirect gas/oil water heaters (*IndGas*). It is also required for storage gas/oil water heaters (*StoGas*) used in combined hydronic systems (*CombHydro*). The value is taken from the Commission's appliance databases or from Commission-approved trade association directories. If the value is omitted for NAECA regulated water heaters, then the default value will be assumed. When boilers are used to fire an indirect gas/oil water heater (*IndGas*), the value of the AFUE or Thermal Efficiency (see below) is used for the recovery efficiency.
- *Tank Size for Direct Fired Tanks(gal).* The storage tank capacity in gallons. This input is applicable to all storage type water heaters. For NAECA covered water heaters, the input is optional.
- *Tank Size for Indirect Fired Tanks (gal).* The indirect fired storage tank capacity in gallons. This input is applicable to all hot water storage tanks that do not have an integral heating element or burner.
- *Combined Hydronic Pump (watts).* This is needed only for electric combined hydronic systems. It is not needed for storage gas or heat pump combined hydronic systems.
- *Rated Input (kBtu/hr for gas and kW for electric):* The energy input rating from the above directories or from the manufacturer's literature. Entries are required for large storage gas/oil water heaters *(LgStoGas)*, indirect gas/oil water heaters (*IndGas*), and when storage gas water heaters (*StoGas*/*LgStoGas*) or heat pump water heaters (*StoHP*) are used in combined hydronic space heating systems (*CombHydro*).
- *Standby Loss (fraction):* The fractional storage tank energy loss per hour during non-recovery periods (standby) taken from the Commission's database cited above. Applicable only to large storage gas water heaters (*LgStoGas*).
- *Tank R-value (hr-ft^2-°F/Btu):* The total thermal resistance of the internally-insulated tank and any external insulation wrap. Applicable to large storage gas/oil (*LgStoGas*) and indirect gas/oil (*IndGas*) water heaters only.
- *Pilot light (Btu/hr)*: The pilot light energy consumption rating from the Commission's database. Applicable only to instantaneous gas (*InstGas*) and indirect gas/oil (*IndGas*) water heaters.

Table R2-9 summarizes the applicability of the inputs for the water heater types recognized by the calculation method.

Table R2-9 – Water Heater Input Summary

Input Item	NAECA Storage Gas	NAECA Storage Electric	NAECA Heat Pump	Instant. Gas	Instant. Electric	Large Storage Gas	Indirect Gas
Energy Factor	Yes	Yes	Yes	Yes	Yes		
Pilot Input, Btu				Yes		Yes	Yes
Efficiency, %				Yes		Yes	Yes
Standby Loss, %						Yes	
Tank Volume, gal.	Yes	Yes	Yes			Yes	Yes
Tank Insulation, R						Yes	Yes
Ext. Insulation, R						Yes	Yes
If Combined Hydronic System:							
Rated Input, kBtuh	Yes					Yes	Yes
Rated Input, kW		Yes	Yes				
Recovery Eff, %	Yes		Yes			Yes	Yes
Pump Input, Watts		Yes				Yes	Yes

Special Water Heating System Credits

This section includes information about water heating auxiliary energy credits, if used. These features are optional capabilities for ACMs and their use for performance compliance requires listing in the *Special Features and Modeling Assumptions* listings of the CF-1R. The *Special Features and Modeling Assumptions* listing shall cross-reference the applicable optional water heating capabilities modeled by the ACM.

WATER HEATING SYSTEMS MISC *(Example Listing)*					
System Name	Solar Savings Fraction or SEF	SRCC Certification Number	Wood Stove Boiler?	Wood Stove Boiler Pump?	Combined Hydronic Pump Power (Watts)
Hydronic	0.00	*None*	*Yes*	*Yes*	60.00
DHW	0.66	*0002-1999-223*	*No*	*No*	

- *System Name.* This is a name corresponding to a system name defined in the Water Heating Systems table.
- *Solar Savings Fraction (SF) or Solar Energy Factor (SEF)*. If the water heating system has a solar system to provide part of the water heating, the SF or SEF is entered in this column. The SF shall be determined using the procedures defined with the optional modeling capability in Chapter 6.
- *SRCC Certification Number. Enter the SRCC certification number for the solar system (OG-300 rated) or the collectors (OG-100 rated). This number is issued by the SRCC when a product is certified.*
- *Wood Stove Boiler (Y/N).* This is a yes/no response on whether or not the system has a wood stove boiler. A credit may be taken for either solar systems or for a wood stove boiler, but not both.
- *Wood Stove Boiler Pump (Y/N).* This is a yes/no response to indicate whether the wood stove boiler has a recirculation pump.
- *Combined Hydronic Pump (Watts):* Required only for electric combined hydronic *(Elec/*, *StoElec/ and InstElec/CombHydro*) systems. Not required for storage gas/oil or heat pump combined hydronic systems (*StoGas/, LgStoGas/, and StoHP/CombHydro*).

2.2.22 Special Features and Modeling Assumptions

This listing shall **stand out and command the attention** of anyone reviewing this form to emphasize the importance of verifying these Special Features and the aspects of these features that were modeled to achieve compliance or the energy use results reported. This listing in the Certificate of Compliance shall include any special features of the building that affect the building's compliance with the standards. For example, water heating features, or auxiliary credits shall be listed under "*Special Features and Modeling Assumptions*" as well as being listed under a special listing of their own. The use of certain non-default values shall also be included in this list. These special default values are indicated in the subsequent text.

This is a free format section for the CF-1R report to note any special features about the building that are needed to verify compliance.

SPECIAL FEATURES AND MODELING ASSUMPTIONS: (*Example Listing)*	Plan	Field
This house has Zonal control with multiple zones, interzone surfaces, and interzone ventilation.		
This building uses metal-framed walls that shall meet mandatory insulation requirements. In many cases sheathing insulation is used in addition to cavity insulation.		
This house uses a non-NAECA large storage gas water heater. Check the SPECIAL WATER HEATER/BOILER DETAILS listing for specifications.		
This house has an attached sunspace with interzone surfaces, custom solar heat gain distribution and sunspace thermal mass elements.		
This house is modeled with reduced infiltration and/or mechanical ventilation. Consequently the homeowner's manual provided by the builder to the homeowner shall include operating instructions for the homeowner on how to use operable windows and/or mechanical ventilation to achieve adequate ventilation.		

2.2.23 Field Verification and Diagnostic Testing

This listing shall **stand out and command the attention** of anyone reviewing this form to emphasize the importance of Field Verification and Diagnostic Testing of these features and the aspects of these features that were modeled to achieve compliance.

Specific features that require diagnostic testing to assure proper installation require field testing and verification by a certified home energy rater (HERS rater) under the supervision of a CEC- approved HERS provider, and shall be listed in this section.

All items in the *Field Verification and Diagnostic Testing* listings shall also report that the installer and HERS rater shall both provide the appropriate CF-6R and CF-4R documentation, respectively, for proper installation, testing, and test results for the features that require verification by a HERS rater. The installer shall document and sign the CF-6R to verify compliance with design and installation specifications. The HERS rater shall document and sign the CF-4R to confirm the use of proper testing procedures and protocol, to report test results, and to report field verification of installation consistent with the design specifications needed to achieve these special compliance efficiency credits.

The ACM shall ask the user if there are vented combustion appliances inside the conditioned space that draw air for combustion from the conditioned space prior to accepting any entry for reduced infiltration or mechanical ventilation. Cooking appliances, refrigerators and domestic clothes dryers are excluded from this requirement. If appliances other than cooking appliances, refrigerators and domestic clothes dryers are present and use conditioned air for combustion, the ACM shall instruct the user that reduced infiltration shall not be modeled when these devices are part of the Proposed Design and block data entries and ACM modeling of reduced infiltration and mechanical ventilation. When the user indicates that such devices are present or when the user models reduced infiltration or mechanical ventilation, the ACM shall report in the *Special Features and Modeling Assumptions* listings that reduced infiltration and/or mechanical ventilation are prohibited from being modeled when vented combustion appliances, not excluded above, are inside conditioned space.

When a *Proposed Design* is modeled with a reduced target infiltration ($CFM50_H$) that corresponds to an SLA less than 3.0, mechanical ventilation is required and shall be reported in the *Field Verification and Diagnostic Testing* listings.

FIELD VERIFICATION AND DIAGNOSTIC TESTING

This house is using reduced duct leakage to comply and shall have diagnostic site testing of duct leakage performed by a certified HERS rater under the supervision of a CEC-approved HERS provider. The results of the diagnostic testing shall be reported on a CF-6R form and list the target and measured CFM duct leakage at 25 pascals.		
This house has tight construction with reduced infiltration and a target blower door test range between 586 and 1250 CFM at 50 pascals. The blower door test shall be performed using the ASTM *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization*, ASTM E 779-03.		
This house is using an HVAC system with all ducts and the air handler located within the conditioned space. This results in a higher distribution efficiency rating due to elimination of conduction losses (losses due to leakage are not changed) and shall be visually confirmed by a certified HERS rater under the supervision of a CEC-approved HERS provider. This verification shall be reported on a CF-6R form.		
WARNING: If this house tests below 586 CFM at 50 pascals, the house shall either be provided with a ventilation opening that will increase the tested infiltration to at least 586 CFM at 50 pascals (SLA = 1.5) OR mechanical supply ventilation shall be provided that can maintain the house at a pressure of at least -5 pascals relative the outside average air pressure while other continuous ventilation fans are operating. Note also that the Commission considers an SLA≤1.5 to be "unusually tight" per the California Mechanical Code.		
WARNING - Houses modeled with reduced infiltration are prohibited from having vented combustion appliances other than cooking appliances, refrigerators and domestic clothes dryers that use indoor air for combustion inside conditioned space.		

2.2.24 Compliance Statement and Signatures

Signature requirements and other details on the compliance statement are included in Section 10-103(a)1 of the Administrative Regulations (Title 24, Part 1).

COMPLIANCE STATEMENT

This certificate of compliance lists the building features and performance specifications needed to comply with the Energy Standards in Title 24, Parts 1 and 6, of the California Code of Regulations, and the Administrative regulations to implement them. This certificate has been signed by the individual with overall design responsibility.

Designer or Owner (per Business & Professions Code)		Documentation Author	
Name	____________________________	Name	____________________________
Title/Firm	____________________________	Title/Firm	____________________________
Address	____________________________	Address	____________________________
City & Zip Code	____________________________	City & Zip Code	____________________________
Telephone	____________________________	Telephone	____________________________
License Number	____________________________	Signature/Date	____________________________
Signature/Date	____________________________		
Enforcement Agency			
Name	____________________________		
Title	____________________________		
Agency	____________________________		
City	____________________________		
Telephone	____________________________		
Signature/Date	____________________________		

3. Defining the Proposed and Standard Designs

The space conditioning energy budget for the residential Standards is a custom budget, that is, the energy that would be used by a building similar to the *Proposed Design*, but that is modified to just meet the requirements of the prescriptive standards. The building that is modeled to create the custom budget is the *Standard Design*. This section of the *ACM Approval Manual* describes how the *Proposed Design* and *Standard Designs* are defined.

For the *Proposed Design,* the user enters information to describe the thermal characteristics of the proposed building envelope including its surface areas, air leakage, shading structures and attachments, thermal mass elements, heating and cooling equipment and distribution systems, and water heating equipment and distribution systems. These inputs are subject to a variety of restrictions which are defined in this section. Modeling assumptions and algorithms for making energy calculations are described in Chapter 4.

The process of generating the *Standard Design* and calculating the custom budget shall be performed automatically by the program, based on the allowed and default inputs for the *Proposed Design* as well as the fixed and restricted inputs and assumptions for both designs. The process of custom budget generation shall not be accessible to program users for modification when the program is used for compliance purposes or when compliance forms are generated by the program. The *Standard Design* generator shall automatically take user input about the *Proposed Design* and create the *Standard Design*, using all the applicable fixed and restricted inputs and assumptions described in this Chapter and in Chapter 4. All assumptions and algorithms used to model the *Proposed Design* shall also be used in a consistent manner in the *Standard Design* building.

The basis of the *Standard Design* is prescriptive Package D, which is contained in Section 151(f) of the Standards. The Package D prescriptive requirements are not repeated here. However, the following sections present the details on how the *Standard Design* is to be developed. Defining the *Standard Design* building involves two steps.

- First, the geometry of the proposed building is modified from the description entered for the *Proposed Design*.
- Second, building features and performance characteristics are modified to meet the minimum requirements of compliance with Package D.

3.1 Building Physical Configuration

Proposed Design. The building configuration is defined by the user through entries for floor areas, wall areas, roof and ceiling areas, fenestration areas, and door areas. Each are entered along with performance characteristics such as U-factors, SHGC, thermal mass, etc. Information about the orientation and tilt is required for walls, fenestration and other elements. The user entries for all of these building elements shall be consistent with the actual building design and configuration. If the ACM models the specific geometry of the building by using a coordinate system or graphic entry technique, the data entered shall be as consistent as necessary to achieve thermal modeling accuracy.

Standard Design. The *Standard Design* building has the same floor area, volume, and configuration as the *Proposed Design*, except that wall and window area are distributed equally between the four main compass points, North, East, South, and West. The details are described below.

3.1.1 Conditioned Floor Area

Proposed Design. The ACM shall require the user to enter the total conditioned floor area of the *Proposed Design* as well as the conditioned slab floor area. The conditioned slab floor area is the area of a slab floor with a minimum slab thickness of 3.5 inches or a minimum heat capacity of 7.0 Btu/ºF-ft² and conditioned space above and unconditioned space or the ground/gravel below. The non-slab conditioned floor area is the total conditioned floor area minus the conditioned slab floor area. Stairwell floor area shall be included in conditioned floor area as the horizontal area of the stairs and landings between two floors of each story of the house. The conditioned slab floor area may be either on-grade or a raised slab.

Standard Design. The total conditioned floor area and the conditioned slab floor area of the *Standard Design* building is the same as the *Proposed Design*.

Note. ACMs shall keep track of the conditioned floor area and shall at least be able to keep separate track of the total conditioned floor area and conditioned slab floor area. These areas are used to determine the default thermal mass for the *Proposed Design* and the thermal mass for the *Standard Design*.

3.1.2 Conditioned Volume

Proposed Design. The volume of the *Proposed Design* is the conditioned volume of air enclosed by the building envelope. The volume shall be consistent with the air volume of the actual design and may be determined from the total conditioned floor area and the average ceiling height or from a direct user entry for volume.

Standard Design. The volume of the *Standard Design* building is the same as the *Proposed Design*.

3.2 Opaque Envelope Elements

3.2.1 Insulation Installation Quality

Proposed Design. The ACM user may specify either *Standard* or *Improved* insulation installation quality for the *Proposed Design*. The presence of *Improved* insulation installation quality shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R. *Improved* insulation installation quality shall be certified by the installer and field verified.

Standard Design. The *Standard Design* shall be modeled with *Standard* insulation installation quality.

Note. Chapter 4 has the modeling rules for Standard and Improved insulation installation quality.

3.2.2 Ceilings/Roofs

Proposed Design. The ACM shall allow a user to enter one or more ceiling/roof areas for the *Proposed Design*. The roof/ceiling areas, construction assemblies, orientations, and tilts modeled shall be consistent with the corresponding areas, construction assemblies, and tilts in the actual building design and shall equal the overall roof/ceiling area with conditioned space on the inside and unconditioned space on the other side. U-factors shall be selected from ACM Joint Appendix IV. If new ceiling and wall construction assemblies do not meet the mandatory minimum U-factor required by Title 24, the building shall not pass compliance. If the *Proposed Design* has *Improved* insulation installation quality, then all ceiling/roof assemblies in the *Proposed Design* are modeled accordingly (see Section 3.2.1 and Chapter 4).

Standard Design. The ceiling/roof areas of the *Standard Design* building are equal to the ceiling/roof areas of the *Proposed Design*. The *Standard Design* roof and ceiling surfaces are assumed to be horizontal (no tilts) and have a U-factor specific to the package D requirements. The U-factors in Table R3-1 shall be used in the *Standard Design* for the appropriate R-value criteria in Package D. The *Standard Design* generator shall consider all exterior surfaces in the *Proposed Design* with a tilt less than 60 degrees as roof elements. Surfaces that tilt 60 degrees or more are treated as walls. The *Standard Design* is modeled with *Standard* insulation installation quality U-factors by correcting the U-factors in Table R3-1 with the standard insulation installation quality adjustment factors for ceilings/roofs from Section 4.2.3.

Table R3-1 – Ceiling/Roof U-factors for the Standard Design

Building Component	R-value Requirement	U-factor	ACM Joint Appendix IV Reference
Roof			
	R-30	0.032	Table IV.1-A7
	R-38	0.026	Table IV.1-A8

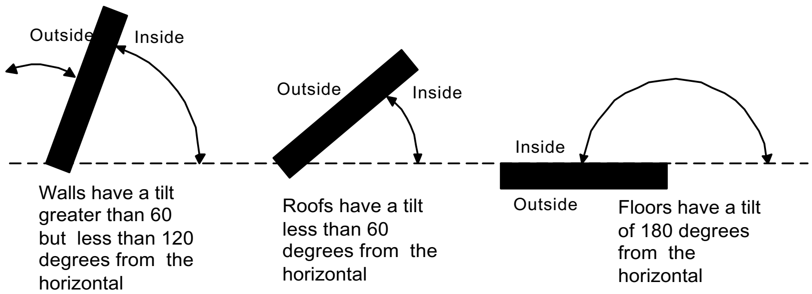

Figure R3-1 – Surface Definitions

Radiant Barriers

Proposed Design. The ACM shall allow the user to input a radiant barrier. The presence of a radiant barrier shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R.

Standard Design. The *Standard Design* shall have a radiant barrier in accordance with Package D requirements. When required by Package D, radiant barriers are required on all ceiling/roof surfaces. See Section 4.2.1 for radiant barrier eligibility criteria.

Cool Roofs

Proposed Design. The ACM shall allow the user to input a cool roof. The presence of a cool roof shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R.

Standard Design. The *Standard Design* shall be modeled without a cool roof.

3.2.3 Walls

Proposed Design. The ACM shall allow a user to enter one or more wall areas for the *Proposed Design*. The wall areas modeled shall be consistent with the corresponding wall areas in the actual building design and the total wall area shall be equal to the gross wall area with conditioned space on the inside and unconditioned space or exterior conditions on the other side. U-factors for *Proposed Design* wall constructions shall be selected from ACM Joint Appendix IV. If the *Proposed Design* has *Improved* insulation installation quality, then walls are modeled accordingly (see Chapter 4). Walls include all opaque surfaces with a slope greater than 60º but less than 120º from the horizontal (see Figure R3-1).

Standard Design. The gross wall area in the *Standard Design* run is equal to the gross wall area of the *Proposed Design*, including knee walls in the ceiling construction of the *Proposed Design*. The gross wall area in the *Standard Design* is equally divided between the four main compass points, North, East, South, and West. Window and door areas are subtracted from the gross wall area to determine the net wall area in each orientation. The *Standard Design* has *Standard* insulation installation quality. U-factors for the *Standard Design* walls shall be those from Table R3-2 for the appropriate Package D R-value criteria multiplied by the standard insulation installation quality factor for walls from Section 4.2.3.

Table R3-2 – Wall U-factors for the Standard Design

Building Component	Package D R-value Criteria	Standard Design U-factor	ACM Joint Appendix IV Reference
Wall	R-13	0.102	Table IV.9-A3
	R-19	0.074	Table IV.9-A5
	R-21	0.069	Table IV.9-A6

3.2.4 Basement Walls and Floors

Proposed Design. Portions of basement walls above grade shall be modeled as conventional walls above grade. For below-grade basement walls, the user shall enter the area at each of three depths: from zero to 2 feet below grade (shallow), greater than 2 feet to 6 feet below grade (medium), and greater than 6 feet below grade (deep). The ACM shall allow users to enter as many wall types as necessary to model the *Proposed Design*. The U-factor, C-factor, and mass characteristics of below-grade walls shall be calculated using methods consistent with ACM Joint Appendix IV. The thermal performance characteristics for the *Proposed Design* below-grade wall constructions shall be the same as the *Standard Design*.

Standard Design. The *Standard Design* shall have the same basement wall areas as the *Proposed Design* and at the same depths. The *Standard Design* basement wall shall be assumed to be a wall with a Heat Capacity of 15.7 Btu/(ft^2-ºF), a thickness of 8 inches, and a uniform R-value of 1.5.

3.2.5 Raised Floors

Proposed Design. In addition to the total conditioned floor area and total conditioned slab floor area (see 3.1.1), ACM users shall enter floor areas for the standard raised floor construction types listed in Table R3-3. The ACM shall require user input to distinguish floor areas and constructions that are over crawl spaces. The U-factor for floor constructions and areas shall be consistent with the actual building design. U-factors shall be those from ACM Joint Appendix IV.

Standard Design. The floor areas of the *Standard Design* are equal to the areas of the *Proposed Design*. The raised floor U-factor for the *Standard Design* is taken from Table R3-3 and depends on whether or not the floor assembly in the *Proposed Design* is located over a crawl space. For this reason, the ACM shall keep track of which raised floor surfaces are over crawl spaces and which are not.

Notes. The effect of a conventional crawl space is modeled with a thermal resistance of R-6; however, for controlled ventilation crawl spaces (an optional capability), the crawl space is modeled as a separate thermal zone and R-6 is not assumed. The R-6 value for a conventional crawlspace shall be automatically calculated by the ACM and shall not be allowed as a user input. The U-factors in Table R3-3 account for the additional R-6.

Table R3-3 – Floor U-factors for the Standard Design

Floor Type	Package D Criteria	U-factor	ACM Joint Appendix IV Reference
Raised Floor (crawl space)	R-19	0.037	IV20-A4
Raised Floor (no crawl space)	R-19	0.048	IV21-A4

3.2.6 Slab-on-Grade Perimeter

Proposed Design. The ACM shall allow users to enter at least two different slab perimeter constructions and their corresponding lengths. Typically, ACMs have no practical limit on the number of slab perimeter constructions that may be entered. The default condition for the *Proposed Design* is that 80% of any slab edge length entered is adjacent to rug-covered (R-2 for carpet and pad) slab and 20% is adjacent to exposed slab on the conditioned side. F-factors for slab loss shall be taken from Joint Appendix IV, Table IV.26 or be calculated using methods consistent with ACM Joint Appendix IV and accurately represent the conditions in the actual building. The ACM shall be able to determine the amount of slab edge adjacent to unconditioned spaces separately from the slab edge adjacent to the outside. In the *Proposed Design*, the F factor(s) may account for slab perimeter insulation for both slab edges exposed to the outside and slab edges adjacent to unconditioned spaces such as garages. In climate zone 16, slab edges adjacent to garages and unconditioned spaces may be considered to be insulated with R-7 insulation and have an F-factor of 0.51.

Standard Design. The total slab perimeter length in the *Standard Design* is the same as in the *Proposed Design*. For the *Standard Design,* the slab edge F-factor, is 0.76 for all climate zones except Climate Zone 16 where the F-factor is 0.51. See Package D. For the *Standard Design* for heated slabs, the slab edge heat loss F-factors shall be those specified in Column B of Joint Appendix IV, Table IV.27 for the installed depth or horizontal distance of the proposed design for all climate zones except climate zone 16 where the F-factor shall be those specified in Column D. For the *Standard Design* unconditioned spaces such as the garage are assumed to be detached.

Table R3-4 – Slab Edge F-factors for the Standard Design

Slab Edge Condition	Package D Criteria	F-factor	ACM Joint Appendix IV Reference
No Insulation	None	0.73	Table IV.26-A1
R-7 Insulation	R-7	0.56	Table IV.26-C7

3.3 Fenestration and Doors

3.3.1 Doors

Proposed Design. ACMs shall allow users to enter at least two different door construction types, their U-factors, areas, and orientations. Door U-factors shall accurately represent the doors installed in the building and be calculated in a manner consistent with ACM Joint Appendix IV.

Standard Design. The *Standard Design* has 40 square feet of door area for each dwelling unit. All doors are assumed to face north and have a U-factor of 0.50 from Joint Appendix IV reference IV28-A3. The net opaque wall area facing north is reduced by 40 ft² for each dwelling unit for the *Standard Design* run.

3.3.2 Fenestration Types and Areas

Proposed Design. ACMs shall allow users to enter fenestration or window types, specify the U-factor, SHGC, area, orientation, and tilt. Performance data (U-factors and SHGC) shall be NFRC values or taken from the CEC default tables.

Standard Design. If the *Proposed Design* fenestration area is less than 20%, the *Standard Design* fenestration area is set equal to the *Proposed Design* fenestration area. Otherwise, the *Standard Design* fenestration area is set equal to 20% of the conditioned floor area. The *Standard Design* fenestration area is distributed equally between the four main compass points—North, East, South and West. The *Standard Design* has no skylights. The net wall area on each orientation is reduced by the fenestration area (and door area) on each facade. The U-factor and SHGC performance factors for the *Standard Design* are taken from the Package D specification.

3.3.3 Overhangs and Sidefins

Proposed Design. ACMs shall allow users to enter a set of basic generic parameters for a description of an overhang and sidefinfor each individual fenestration or window area entry. The basic parameters shall include *Fenestration Height, Overhang/Sidefin Length, and Overhang/Sidefin Height.* ACM user entries for overhangs may also include *Fenestration Width, Overhang Left Extension* and *Overhang Right Extension.* ACM user entries for sidefins may also include *Fin Left Extension* and *Fin Right Extension* for both left and right fins. (See Sections 2.2.9 and 2.2.10.)

Standard Design. The *Standard Design* does not have overhangs.

3.3.4 Solar Heat Gain Coefficients

Proposed Design. ACMs shall require the user to enter the fenestration Solar Heat Gain Coefficient for each window, skylight, or other fenestration system type. This requirement may be met by having the user select from a default list of fenestration systems or by direct entry using NFRC-certified values for windows, doors with glass or skylights. In addition, for each fenestration element the ACM shall allow the user to select an exterior shading treatment from the lists given in Table R3-7. The ACM will then determine the overall SHGC for the complete fenestration system based on the fenestration SHGC and the SHGCs assigned to the Commission-approved exterior shading devices and assigned interior shading devices from Table R3-5 and Table R3-7.

Standard Design. The *Standard Design* fenestration Solar Heat Gain Coefficients (SHGCs) are determined by the appropriate Package D specifications for the applicable climate zone. Note that the frame type and the presence or absence of muntins or dividers is irrelevant for the *Standard Design* as the Package D values for $SHGC_{fen}$ and the U-factor include the effects of fenestration features such as framing, dividers, and muntins.

3.3.5 Interior Shading Devices

Internally, ACMs shall use two values to calculate solar heat gain through windows: $SHGC_{open}$ and $SHGC_{closed}$. $SHGC_{open}$ is the total solar heat gain coefficient of the fenestration and its exterior shading device when the operable interior shading device is open. $SHGC_{closed}$ is the total solar heat gain coefficient when the interior shading device is closed. $SHGC_{open}$ is the setting that applies when the air conditioner is not operating, which typically is most of the 24-hour period, while $SHGC_{closed}$ applies only for periods when the air conditioner operates. The *Standard Design* values for these SHGCs are shown in Table R3-6 below. $SHGC_{open}$ and $SHGC_{closed}$ are not user specified inputs. See Chapter 4 for more details.

The ACM shall require the user to directly or indirectly specify $SHGC_{fen}$ and frame type. The ACM shall assign an interior shading device as listed in Table R3-5 and require the user to specify exterior shading device as listed in Table R3-7. The ACMs shall calculate the overall SHGC for the fenestration with shading devices as shown in Chapter 4.

For both the *Proposed Design* and the *Standard Design,* all windows are assumed to have draperies and skylights are assumed to have no interior shading.

Table R3-5 – Allowed Interior Shading Devices and Recommended Descriptors

Recommended Descriptor	Interior Shading Attachment Reference	Solar Heat Gain Coefficient
Standard	Draperies or No Special Interior Shading - Default Interior Shade	0.68 (see Note 1)
None (see Note 2)	No Interior Shading - Only for Skylights (Fenestration tilt <60 degrees)	1.00

Note (general): No other interior shading devices or attachments are allowed credit for compliance with the building efficiency standards.

Note 1: Standard shading shall be assumed for all fenestration with a tilt of 60 degrees or greater from horizontal.

Note 2: *None* is the default interior shading device in the standard and proposed design for fenestration tilted less than 60 degrees from horizontal (skylights) and is only allowed for fenestration tilted less than 60 degrees from horizontal (skylights), i.e. *None* is not an interior shading option for ordinary vertical windows

Table R3-6 – Standard Design *Shading Conditions*

	Package Specification	
Characteristic	$SHGC_{fen}$ = NR	$SHGC_{fen}$ = 0.37
$SHGC_{fen}$	0.67	0.37
$SHGC_{open}$	0.649	0.358
$SHGC_{closed}$	0.614	0.339
Glazing	Double Clear	Double Low Solar Low E
Interior Shade	Drapes (*Standard*)	Drapes (*Standard*)
$SHGC_{int}$	0.68	0.68
Exterior Shade	Bugscreen (*Standard*)	BugScreen (*Standard*)
$SHGC_{ext}$	0.76	0.76

3.3.6 Exterior Shading Devices

Proposed Design. The ACM shall require the user to either accept the default exterior shading device or select from a specific Commission-approved list of exterior shading devices for each fenestration element. The default choice for exterior shading device is *Standard,* which is assigned an average SHGC of 0.76. The ACM Compliance Supplement shall explicitly indicate that credit is allowed only for one exterior shading device. See Table R3-7 for other choices.

Standard Design. The *Standard Design* shall assume the default exterior shading, which is the standard bug screen.

Table R3-7 – Allowed Exterior Shading Devices and Recommended Descriptors

Recommended Descriptor	Exterior Shading Device Reference	Solar Heat Gain Coefficient
Standard	Bug Screen or No Shading	0.76
WvnScrn	Woven SunScreen (SC<0.35)	0.30
LvrScrn	Louvered Sunscreen	0.27
LSASnScrn	LSA Sunscreen	0.13
RlDwnAwng	Roll-down Awning	0.13
RlDwnBlnds	Roll -down Blinds or Slats	0.13
None (see Note 1)	For skylights only - No exterior shading	1.00

Note 1: None is the default for fenestration tilted less than 60 degrees from horizontal (skylights) and is only allowed for fenestration tilted less than 60 degrees from horizontal (skylights), i.e. None is not an exterior shading option for ordinary vertical windows.

3.4 Thermal Mass

Prescriptive Package D, the basis of the *Standard Design*, has no thermal mass requirements. Package D and the performance approach assume that both the *Proposed Design* and *Standard Design* building have a minimum mass as a function of the conditioned area of slab floor and non-slab floor.

Proposed Design. The *Proposed Design* will be modeled with the same thermal mass as the Standard design unless the Proposed Design is a high mass building as defined below.

Standard Design. The conditioned slab floor in the *Standard Design* is assumed to be 20% exposed slab and 80% slab covered by carpet or casework. The non-slab floor in the *Standard Design* is assumed to be 5% exposed with two inch thick concrete with the remainder low-mass wood construction. No other mass elements are modeled in the *Standard Design*. The *Standard Design* mass is modeled with the following characteristics.

- The conditioned slab floor area (slab area) shall have a thickness of 3.5 inches; a volumetric heat capacity of 28 Btu/ft^3-°F; a conductivity of 0.98 Btu-in/hr-ft^2-°F. The exposed portion shall have a surface conductance of 1.3 Btu/hr-ft^2-°F (no thermal resistance on the surface) and the covered portion shall have a surface conductance of 2.0 Btu/hr-ft^2-°F, typical of a carpet and pad.
- The "exposed" portion of the conditioned non-slab floor area shall have a thickness of 2.0 inches; a volumetric heat capacity of 28 Btu/ft^3-°°F; a conductivity of 0.98 Btu-in/hr-ft^2-°°F; and a surface conductance of 1.3 Btu/hr-ft^2-°F (no added thermal resistance on the surface). These thermal mass properties apply to the "exposed" portion of non-slab floors for both the *Proposed Design* and *Standard Design*. The covered portion of non-slab floors is assumed to have no thermal mass.

Definition of High Mass Building. Additional thermal mass in the proposed design may only be modeled when the *Proposed Design* is a high mass building. A high mass building has mass equivalent to 30% of the conditioned slab floor area being exposed slab and 70% slab covered by carpet or casework, and 15% of the conditioned non-slab floor area being exposed with two inch thick concrete with the remainder low-mass wood construction. ACMs may let users indicate a high mass design before entering mass elements for the proposed design, or ACMs can let users enter mass elements, but only consider them in the proposed design if the building qualifies as a high mass building. Thermal mass equivalency is determined through the concept of the Unit Interior Mass Capacity (UIMC) described in ACM RB-2005. The thermal mass of the *Proposed Design,* other than the default *Standard Design* mass is only modeled and displayed on compliance output if the *Proposed Design* qualifies as a high mass building.

3.5 Infiltration/Ventilation

The intentional or unintentional replacement of conditioned indoor air by unconditioned outdoor air creates heat gains or heat losses for a conditioned building. This exchange of indoor and outdoor air occurs for all buildings to a greater or lesser extent. Mechanical ventilation gives a certain degree of control of the rate of this exchange and depending on the balancing of the ventilation may create building pressurization.

Proposed Design. As a default, ACMs shall not require the user to enter any values related to infiltration or mechanical ventilation for air quality and shall set the infiltration level to be the same as the standard design. Specific data on infiltration may be entered if the building will be diagnostically tested during building construction or if a qualifying air-retarding wrap is specified.

Air Retarding Wrap. An air retarding wrap can qualify for a default reduction in Specific Leakage Area (SLA) of 0.50 without confirmation by diagnostic testing. The air retarding wrap shall be tested and labeled by the manufacturer to comply with ASTM E1677-95, *Standard Specification for an Air Retarder (AR) Material or system for Low-Rise Framed Building Walls* and have a minimum perm rating of 10. The air-retarding wrap shall be installed per the manufacturer's specifications that shall be provided to comply with ASTM E1677-95 (2000). The air retarding wrap specifications listed above shall also be reported in the *Special Features and Modeling Assumptions* listings when an air retarder is modeled by the ACM.

Reduced Infiltration due to Duct Sealing. The default infiltration (no diagnostic testing and measurement of infiltration) credit for reduced duct leakage is also an SLA reduction of 0.50. The ACM shall automatically apply this credit when the *Proposed Design* has sealed and tested ducts. The use of this SLA reduction credit for Low-leakage HVAC ducts shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R.

Diagnostic Testing for Reduced Infiltration. Neither of the above credits shall be taken if the user chooses a diagnostic testing target for reduced infiltration. When the user chooses diagnostic testing for reduced infiltration, the diagnostic testing shall be performed using fan pressurization of the building in accordance with ASTM E 779-03, *Standard Test Method for Determining Air Leakage Rate by Fan Pressurization* and the equipment used for this test shall meet the instrumentation specifications found in ACM RF. The specifications for diagnostic testing and the target values specified above shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R.

If the user specifies they will be using diagnostic testing during construction, for either reduced infiltration or reduced infiltration with mechanical ventilation, the ACM shall require the user to enter a target value for measured $CFM50_H$ or the SLA corresponding to the target $CFM50_H$, and, if mechanical ventilation is to be used, the wattage and cfm of the ventilation supply and exhaust fans. Note that when the *Proposed Design* target value for reduced infiltration falls below a value corresponding to an SLA of 3.0, mechanical ventilation is required and this requirement shall be reported as described in Chapter 2. Whenever mechanical ventilation is modeled (required or not), the volumetric capacity modeled shall be at least 0.047 cfm/ft^2 of conditioned floor area. This minimum capacity is needed to provide adequate ventilation for indoor air quality. If the user attempts to model total mechanical volumetric capacity (balanced + unbalanced) less than 0.047 cfm/ft^2, then the ACM shall indicate an input error and automatically block compliance output.

Tested infiltration below a value corresponding to an SLA of 1.5 is not allowed unless mechanical *supply* ventilation is installed adequate to maintain the residence at a pressure greater than -5 pascals relative to the outside average air pressure with other continuous ventilation fans operating.

Standard Design. The *Standard Design* does not use mechanical ventilation and assumes infiltration corresponding to a Specific Leakage Area (SLA) of 4.9 for ducted HVAC systems and an SLA of 3.8 for non-ducted HVAC systems. See Chapter 4 for more detailed information.

3.5.1 Free Ventilation Area

Proposed Design: Free ventilation area for the proposed design is calculated by the ACM based on the types and areas of windows specified in the *Proposed Design*. The free ventilation area is modeled as 20% of the fenestration area for hinged type windows such as casements, awnings, hoppers, patio doors and French doors that are capable of a maximum ventilation area of approximately 80% of the rough frame opening. If the ACM user increases the ventilation area for hinged type windows, the ACM shall also consider the possible effect of fixed glazing in the building which has no free ventilation area (window opening type *Fixed*). The ACM user may account for additional free ventilation area by entering the total area for sliding windows, the total area for hinged windows, and the total area of fixed windows. The ACM shall verify that the total area entered for these three types is the same as the total area of windows calculated elsewhere or the ACM may determine the area of fixed windows by subtracting the slider window area and the hinged window area from the total window area if it is less than the total window and skylight area. If the total window and skylight area is less than the area specified for sliding windows and hinged windows the ACM shall reduce the area of hinged windows by the difference. The total ventilation area is calculated from the areas of the three possible fenestration opening types, as shown below:

Equation R3-1
$$Vent_{Area} = (Area_{Slider} \times 0.1) + (Area_{Hinged} \times 0.2) + (Area_{Fixed} \times 0.0)$$

The ACM's ability to accept a customized ventilation area is an optional capability. When this optional capability is used, the fact that the user entered a customized free ventilation area and the total areas of each of these three fenestration opening types shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R. Note that the maximum free ventilation area that may be modeled by any ACM for compliance purposes is 20% of the total area of windows and skylights assuming that all windows and skylights are hinged.

Free ventilation area is the adjusted area taking into account bug screens, window framing and dividers, and other factors.

Standard Design: The *Standard Design* value for free ventilation area is 10% of the fenestration area (rough frame opening). This value assumes that all windows are opening type *Slider*. The approved ACM compliance manual shall note that fenestration-opening type *Slider* also may be selected by the user or automatically used by the ACM as a default or "*Standard*" opening type.

3.5.2 Ventilation Height Difference

Proposed Design: The default assumption for the *Proposed Design* is 2 ft for one story buildings and 8 ft for two or more stories. Greater height differences may be used with special ventilation features such as high, operable clerestory windows. In this case, the height difference entered by the user is the height between the average center height of the lower operable windows and the average center height of the upper operable windows. Such features shall be fully documented on the building plans and noted in the *Special Features and Modeling Assumptions* listings of the CF-1R.

Standard Design: The *Standard Design* modeling assumptions for the elevation difference between the inlet and the outlet is two feet for one story buildings and eight feet for two or more stories.

3.6 Heating and Cooling System

3.6.1 System Type

Proposed Design. ACMs shall require the user to enter simple heating and cooling seasonal efficiencies that characterize basic package single zone HVAC systems used to heat and/or cool the modeled building. ACMs shall be able to distinguish what fuel is being used to heat the building and what fuel is used to cool the dwelling. This may be based on direct user input or indirectly determined from the user's selection of HVAC equipment types. ACMs shall require the user to enter the type of distribution system that is used in the proposed design.

For building using more than one system type, equipment type or fuel type, and the types do not serve the same floor area, the user shall either zone the building or enter the floor area served by each type. The ACM shall weight the load to each type by zone or floor area.

For floor areas served by more than one heating system, equipment, or fuel type, the user of the program shall specify which system, equipment, and fuel type satisfies the heating loads.

For floor areas served by more than one cooling system, equipment, or fuel type, the user of the program shall specify which system, equipment, and fuel type satisfies the cooling loads.

Standard Design. The standard heating and cooling system for central HVAC systems is a single zone system with ducts in the attic. The standard heating and cooling system for non-central HVAC systems is an unducted system.

For buildings using more than one system, equipment, or fuel type where each conditions a different floor area within the building, the *Standard Design* shall use the weighted allocation of loads to each system, equipment, or fuel type as used for the *Proposed Design.*

For floor areas in the proposed design served by more than one system, equipment, or fuel type, loads for those floor areas shall be assumed to be satisfied in the *Standard Design* as specified in Section 3.6.3 and 3.6.4 for each system, equipment, and fuel type the user specifies in the proposed design.

3.6.2 No Cooling

Proposed Design: When the *Proposed Design* has no air conditioning system, the *Proposed Design* is required to model a split system air conditioner meeting Package D requirements. If the heating system is ducted, the location and R-value of those ducts shall be used for the cooling system. If the heating system has no ducts the cooling system ducts shall be modeled as located in the attic, insulated to Package D levels. Since the Standard Design has these same features, there is no penalty or credit related to the lack of ducts.

Standard Design: The *Standard Design* has a split system air conditioning system meeting the Package D requirements and with air distribution ducts located in the attic. The *Proposed Design* is assumed to have the same features so there is no penalty or credit.

3.6.3 Heating Equipment

Proposed Design. ACMs shall be able to model the basic types of heating equipment and the efficiency metrics listed in the Appliance Efficiency Regulations, except for combined hydronic space and water heating systems, which is an optional modeling capability. ACMs shall require the user to enter the basic information to model the energy use of these pieces of equipment. At a minimum this includes some type of seasonal efficiency for heating and information on whether or not the HVAC system has ducts and the performance characteristics of those ducts. With gas heating systems, the ACM shall require the user to identify if the gas heating system is ducted or non-ducted. The gas heating system type shall also be identified: central gas furnace or non-central gas furnace system. If the system is a non-ducted non-central gas furnace system, the ACM shall require the user to select the type and size of the equipment from the Appliance Efficiency Regulations for Gas Fired Wall Furnaces, Floor Furnaces and Room Heaters, where the system size, as a default, may be determined as 34 Btu/hour per square foot of conditioned floor area.

Standard Design. When electricity is used for heating, the heating equipment for the *Standard Design* shall be an electric split system heat pump with a Heating Seasonal Performance Factor (HSPF), meeting the Appliance Efficiency Regulations requirements for split systems. However, when the *Proposed Design* uses a single package heat pump, the *Standard Design* shall have a heat pump with an HSPF meeting the Appliance Efficiency Regulations requirements for single package equipment. When a *Proposed Design* uses both a single package heat pump and another type of electric heat, the *Standard Design* HSPF shall be a conditioned floor area weighted average of the minimum single package HSPF for the floor area conditioned by single package equipment and the minimum split system HSPF for the remaining floor area. When electricity is not used for heating, the equipment used in the *Standard Design* building shall be either a gas furnace with an Annual Fuel Utilization Efficiency (AFUE) meeting the Appliance Efficiency Regulations minimum efficiency for central systems, or shall be a gas furnace of the type specified in the proposed design at the efficiency level shown in the Appliance Efficiency Regulations for Gas Fired Wall Furnaces, Floor Furnaces and Room Heaters. When a *Proposed Design* uses both a nonelectric central system and another type of nonelectric system, the *Standard Design* efficiency shall be a conditioned floor area weighted average of the efficiencies of the heating equipment.

Note: Minimum efficiencies for heat pumps change effective January 23, 2006 (see Table C-2 of the Appliance Efficiency Regulations). The *Standard Design* shall use those new efficiencies after that date.

3.6.4 Cooling Equipment

Proposed Design. ACMs shall be able to model the basic types of cooling equipment and the efficiency metrics listed in **Error! Reference source not found.**. ACMs shall require the user to enter the basic information to model the energy use of these pieces of equipment. At the minimum this includes some type of seasonal distribution system efficiency for cooling, identification of whether the cooling system is ducted or non-ducted and whether it is central or non-central and the type of equipment as identified in the Appliance Efficiency Regulations. If the cooling system is non-ducted, non-central, the ACM shall require the user to select the type and size of the equipment from the Appliance Efficiency Regulations for Room Air Conditioners, Room Air Conditioning Heat Pumps, Package Terminal Air Conditioners and Package Terminal Heat Pumps.

Standard Design. The cooling system for the *Standard Design* building with a central system shall be of the same type identified in the Appliance Efficiency Regulations and selected for the proposed design with a SEER meeting the Appliance Efficiency Regulations minimum requirements. For non-ducted non-central cooling equipment, the efficiencies shall be from the Appliance Efficiency Regulations for Room Air Conditioners, Room Air Conditioning Heat Pumps, Package Terminal Air Conditioners and Package Terminal Heat Pumps for the type and size in the *Proposed Design* where the size may be a user input or shall default to 24 Btu per hour per square foot of conditioned floor area. When a *Proposed Design* uses both a split system air conditioner and another type of air conditioner, the *Standard Design* SEER shall be a conditioned floor area weighted average of the SEERs of the cooling equipment.

Note: Minimum efficiencies for air conditioners and heat pumps change effective January 23, 2006 (see Table C-2 of the Appliance Efficiency Regulations). The *Standard Design* shall use those new efficiencies after that date.

3.6.5 Refrigerant Charge or TXV

Proposed Design. The ACM shall allow the user to indicate if split system air conditioners or heat pumps have diagnostically tested refrigerant charge or a field verified thermostatic expansion valve (TXV). This applies only to split system air conditioners and heat pumps. It does not apply to package air conditioners and heat pumps. These features require field verification or diagnostic testing and shall be reported in the *Field Verification and Diagnostic Testing* listings on the CF-1R.

Standard Design. If a split system ducted central air conditioner or heat pump (*SplitAirCond* or *SplitHeatPump*) is used for the *Proposed Design* then the cooling system used in the *Standard Design* building shall be modeled with either diagnostically tested refrigerant charge or a field verified TXV if required by Package D.

3.6.6 Air Distribution Ducts

Proposed Design. ACMs shall be able to model the basic types of HVAC distributions systems and locations listed in Table R2-3. As a default, for ducted systems HVAC ducts and the air handler are located in the attic. Proposed HVAC systems with a duct layout and design on the plans may locate the ducts in the crawlspace or a basement if the layout and design specify that all of the supply registers are located in the floor or within two feet of the floor, and show the appropriate locations for the ducts. Otherwise, the default location is the attic as shown in Table R4-11. If all supply registers are at the floor, but the building has both a crawlspace and a basement, the duct location may be taken as a floor area weighted average of the duct efficiencies of a crawlspace and a basement. If the modeled duct location is not in the attic, the ACM shall specify that all supply registers for the building are located in the floor or within two feet of the floor, and this shall be noted in the *Special Features and Modeling Assumptions* listings of the CF-1R.

Proposed HVAC systems with a complete duct design, including the duct layout and design on the plans, may allocate duct surface area in more detail in the ACM model but the distribution of duct surface areas by location shall appear on the *Field Verification and Diagnostic Testing* list of the CF-1R. The HERS rater shall verify the existence of duct design and layout and the general consistency of the actual HVAC distribution system with the design. The HERS rater shall also measure and verify adequate fan flow, see Section 3.6.9.

The ACM shall allow users to specify if they will be using diagnostic testing of HVAC distribution efficiency of a fully-ducted system during the construction of the building to confirm the modeling of improved HVAC distribution efficiency measures such as duct leakage. The default shall be that no diagnostic testing will be done. Duct efficiency credits may not be taken and diagnostic testing may not be done on any HVAC system that uses nonducted building cavities such as plenums or platform returns, to convey conditioned air unless they are defined or constructed with sealed sheet metal or duct board Building cavities, including support platforms, may contain ducts. If the user does not select diagnostic testing, the ACM shall require users to input at least two (2) basic parameters to determine HVAC distribution efficiency: the total conditioned floor area of the building as specified above and the R-value of the duct insulation which may be defaulted to the minimum duct insulation requirements. Additional data may be required to determine seasonal distribution system efficiency. The default input parameters are presented in Chapter 4. If the user specifies diagnostic testing to be performed during construction, the ACM shall prompt the user to enter the data described Section 4.8.2, *Seasonal Distribution System Efficiency* and shall report all required measurements and the features used to achieve higher HVAC distribution efficiencies in the *Field Verification and Diagnostic Testing* listings on the CF-1R. When the user chooses diagnostic testing, the diagnostic testing shall be performed as described in ACM RC-2005.

Standard Design. The standard heating and cooling system for central systems is modeled with non-designed air distribution ducts located in an attic space, with the duct leakage factor for sealed and tested new duct systems (see Table R4-13) and a radiant barrier in climate zones where required by Package D. The *Standard Design* duct insulation is determined by the Package D specifications for the applicable climate zone. The *Standard Design* building is assumed to have the same number of stories as the *Proposed Design* for purposes of determining the duct efficiency. HVAC distribution system efficiencies shall be calculated using the algorithms and equations in Chapter 4 of this manual for both the *Proposed Design* and the *Standard Design*. The *Standard Design* calculation shall use the default values of that procedure. For non-central HVAC systems, the *Standard Design* shall have no ducts.

3.6.7 Fan Energy

Proposed Design. The ACM shall allow the user to specify whether or not the proposed design will take credit for reduced fan Watts, see Chapter 4. The credit for reduced fan Watts shall be reported in the *Special Features and Modeling Assumptions* listings on the CF-1R.

Standard Design. The *Standard Design* shall have the default fan watts.

3.6.8 Maximum Cooling Capacity Credit

Proposed Design. The ACM shall allow the user to specify that the maximum cooling capacity determined using ACM RF-2005 will be met. Compliance credit may be taken if the installed cooling capacity is less than or equal to the maximum cooling capacity, and the system will have verified adequate airflow, sealed and tested ducts and proper refrigerant charge (or alternatively a TXV). The ACM shall not allow compliance credit to be taken for cooling capacity less than the maximum cooling capacity if any of these other features are not also specified for compliance. If this alternative is not used, the *Proposed Design* shall make no adjustment to the duct efficiency of the *Standard Design* for this feature. If compliance credit is taken for this alternative, it must be reported in the *Field Verification and Diagnostic Testing* listings of the CF-1R along with the other measures that are required to take the credit.

Standard Design. When this alternative is selected, the *Standard Design* shall model the Maximum Allowable Cooling Capacity as calculated using the procedure in ACM RM-2005, otherwise the *Standard Design* shall match the *Proposed Design*.

3.6.9 Adequate Airflow

Proposed Design. The default for the Proposed Design assumes inadequate airflow (see Section 4.7.4). However, compliance credit may be taken if adequate airflow is diagnostically tested using the procedures of Appendix RE. Adequate airflow shall be reported in the *Field Verification and Diagnostic Testing* listings of the CF-1R.

Standard Design. The standard design shall assume inadequate airflow as specified in section 4.7.4.

3.7 Water Heating

Proposed Design. ACMs shall be able to model the basic types of water heaters listed in Table R2-7, the water heating distribution system choices (within the dwelling unit) listed in Table R3-8 (and R2-5), and the multiple dwelling unit recirculating system control choices listed in R3-9 (and R2-6). ACM users shall specify the following information about each water heating system:

- The number of dwelling units served by the water heating system (needed only when the system serves multiple dwelling units).
- The number of water heaters that are a part of the system
- The performance characteristics of each water heater:
  - For gas water heaters with an input rating of 75,000 Btu/h or less and for electric water heaters with an input rating of 12 kW or less, the energy factor (EF) is entered.
  - For small instantaneous gas or oil water heaters as defined in the Appliance Efficiency Standards, the Energy Factor (EF) is entered.
  - For large instantaneous gas or oil water heaters as defined in the Appliance Efficiency Standards, the thermal efficiency (TE), pilot light energy (Pilot), standby loss (SBE or SBL), tank surface area (TSA), and R-value of exterior insulation wrap (REI) is entered.
  - For large storage water heaters, the hourly jacket loss, thermal efficiency (TE), and type (indirect or direct) and pilot light energy (Pilot) are entered. If not available from the manufacturer, jacket loss may be calculated from the tank surface area (TSA), the R-value of exterior insulating wrap (REI) and the standby loss expressed either as a fraction of the heat content of the stored water (SBL) or in Btu/hr (SBE). Tank surface area may also be calculated based on the tank capacity in gallons. See ACM RN for details.
- Information about any solar or wood stove supplementary heating that is provided. See ACM Appendix RG for details.
- The type of distribution system used within the dwelling unit. This is a selection from Table R3-8. For recirculating systems that serve multiple dwelling units, the brake horsepower of the circulation pump (hp), the efficiency of the pump, the efficiency of the motor, and the type of control (choose from Table R3-9).
- If multiple water heating systems serve a single dwelling unit, then the ACM shall keep track of the conditioned floor area served by each water heating system.
- For water heating systems serving multiple dwelling units, the ACM shall keep track of the dwelling units served by each system.

For systems serving multiple dwelling units, the characteristics of an average or typical dwelling unit, e.g. conditioned floor area and number of stories (within the dwelling unit), may be used in making calculations.

Table R3-8 – Water Heater Distribution System Choices (Within the Dwelling Unit)

Distribution System Measure	Code
Pipe Insulation (kitchen lines = 3/4 inches) – Standard Case	STD
Pipe Insulation (all lines)	PIA
Standard pipes with no insulation	SNI
Point of Use	POU
Parallel Piping	PP
Recirculation (no control)	RNC
Recirculation + timer control	RTm
Recirculation + temperature control	RTmp
Recirculation + timer/temperature	RTmTmp
Recirculation + demand control	RDmd

Table R3-9 – Multiple Dwelling Unit Recirculating System Control Choices

Distribution System Measure	Code
No Control	NoCtrl
Timer Control	STD

Standard Design. For multiple dwelling unit systems, the *Standard Design* shall have the same number of water heating systems as the *Proposed Design*. For single dwelling unit systems, the *Standard Design* shall have one water heating system, regardless of the number of systems in the *Proposed Design*. Each *Standard Design* water heating system shall have the characteristics specified in Table R3-10.

Table R3-10 – Specification of Standard Design Water Heater

<table>
<tr><td rowspan="4">Does the water heating system serve a single dwelling unit?</td><td>Yes</td><td colspan="5">Standard design is a 50 gallon gas or LPG storage type water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.

EF is equal to 0.575, which is the NAECA minimum for the 50 gallon basecase water heater. EF = 0.67 – 0.0019 V, where V is the volume in gallons.

A standard distribution system with no circulation system. Actual efficiency depends on the size of the dwelling unit and the number of stories.</td></tr>
<tr><td rowspan="3">No</td><td rowspan="3">Does the proposed water heating system have a storage tank?</td><td rowspan="2">Yes</td><td rowspan="2">Is the input rating of each water heater in the proposed design less than or equal to 75,000 Btu/h or if electric, less than or equal to 12 kW.</td><td>Yes</td><td>Standard design is one or more NAECA gas or LPG water heater. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.

If the total storage volume of the proposed design is less than 100 gallons, then the standard design is single water heater with a storage volume equal to the total storage volume of the proposed design.

If the total storage volume of the proposed design is larger than 100 gallons, then the standard design shall have multiple 100 gallon water heaters. The number of water heaters is equal to the total storage capacity of the proposed design divided by 100 and rounded up.

The EF of each 100 gallon water heater shall be 0.48, which is the NAECA minimum. If the standard design is less than 100 gallons, then the EF = 0.67 – 0.0019 V.

See specification of distribution system in the note below.</td></tr>
<tr><td>No</td><td>Standard design is composed of the same number of large storage gas or LPG water heaters as in the proposed design with a storage volumes the same as the storage volumes of the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.

The thermal efficiency is 0.80 and stand-by losses are as specified in Table 113A.

See specification of distribution system in the note below.</td></tr>
<tr><td>No</td><td colspan="3">Standard design is the same number of natural gas or LPG instantaneous water heaters as in the proposed design with input ratings equal to those in the proposed design. If natural gas is available at the site, the standard design is a gas water heater, otherwise it is LPG.

Thermal efficiency of the instantaneous water heaters shall be equal to the requirements in Section 111.

See specification of distribution system in the note below.</td></tr>
</table>

The *Standard Design* distribution system for systems serving multiple dwelling units is described in more detail below:

1. When the distribution system is a recirculating system, the standard design shall be a recirculating system with timer controls, e.g. the coefficients in Table RG-5 for “Timer Controls” shall be used in the calculation of energy use for the standard design, otherwise the standard design shall be a non-recirculating system.
2. Pipe length and location in the standard design shall be the same as the proposed design. There are three possible locations defined in ACM RG-2005.
3. The pipes in the recirculation system shall be insulated in accordance with Section 150(j).
4. The pumping head and motor size for the standard design shall be equal to the pumping head and motor size in the proposed design.

5. The motor efficiency of the recirculation pump in the standard design shall be equal to the requirements in the CEC appliance efficiency standards, e.g. NEMA high efficiency motors.
6. The distribution losses within the dwelling units shall be calculated based on one story and the average dwelling unit size for all the dwelling units served by the water heating system (see RG-3.2).

3.8 Additions and Alterations

There are three compliance approaches for additions to and alterations of existing buildings:

- Whole Building Approach
- Addition Alone Approach
- Existing + Addition + Alteration Approach

Each of these approaches and their accompanying rules are described in the following sections. The existing + addition + alteration approach is the most flexible.

3.8.1 Whole Building Approach

The entire proposed building, including all additions and/or alterations, is modeled the same as a newly constructed building. The building complies if the Proposed Design uses equal or less energy than the Standard Design.

Except in cases where the existing building is being completely remodeled, this is usually a difficult standard to meet as the existing building usually does not meet current standards and must be substantively upgraded.

Proposed Design. Entire building (including additions, alterations and existing building) modeled the same as new construction as described throughout the ACM manual.

Standard Design. Entire building modeled the same as new construction as described throughout the ACM manual.

3.8.2 Addition Alone Approach

The proposed addition alone is modeled the same as a newly constructed building except that the internal gains are prorated to the size of the dwelling, and any surfaces such as walls or ceilings that are between the existing building and the addition are modeled as adiabatic and not included in the calculations. Water heating is not modeled when using this approach. The addition complies if the Proposed Design uses equal or less space heating and space cooling TDV energy than the Standard Design.

The Addition Alone Approach shall not be used when alterations to the existing building are proposed or when there are proposed modifications to existing water heating or when additional water heaters are being added. Instead, the Existing + Addition + Alteration approach shall be used for these cases. Note that modifications to any surfaces between the existing building and the addition are part of the addition and are not considered alterations.

This approach works best when the energy features in the addition are similar to those in the prescriptive packages.

Proposed Design. The user shall indicate that an addition alone is being modeled and enter the conditioned floor area of the addition. The number of dwelling units shall be set to the fractional dwelling unit as specified in Section 4.1.4. Any surfaces that are between the existing building and the addition are not modeled or treated as an adiabatic surfaces. All other features of the addition shall be modeled as for a newly constructed building.

When an existing HVAC system is extended to serve the addition, the Proposed Design shall assume the same efficiency for the HVAC equipment as the Standard Design.

When a dual-glazed greenhouse window or a dual-glazed skylight is installed in an addition, the Proposed Design U-factor shall be the lower of the Standard Design U-factor or the NFRC rated U-factor for the greenhouse window or skylight

Standard Design. The addition alone is modeled the same as newly constructed building as described throughout the ACM manual.

3.8.3 Existing + Addition + Alteration Approach

The proposed building, including all additions and/or alterations, is modeled with tags that describe each energy feature as part of the existing building or the addition or the alteration. The ACM uses the tags to create an existing + addition + alteration (abbreviated e+ad+al) standard design in accordance with the rules in this section that takes into account whether altered components meet or exceed the prescriptive alteration levels. The energy use of the e+ad+al Proposed Design shall use equal or less energy than the e+ad+al Standard Design.

Valid tags include:

- Existing - building features that currently exist and will not be altered
- Altered – building features that are being altered from existing conditions but are not part of an addition
- Added - building features that are being added as part of an addition
- Deleted – existing building features that are being deleted as part of an addition or alteration

This section describes the case where the information about the e+ad+al is contained in a single input file using tags as needed for each zone, opaque surface, fenestration surface, mass surface, etc. Alternate input approaches that provide the information necessary to calculate and provide compliance documentation consistent with the descriptions in this section are allowed with approval from the Commission.

Proposed Design. The user shall indicate that an e+ad+al is being modeled and shall enter the appropriate tags for surfaces or systems. Features that are being altered will need to be paired by the ACM with the existing feature it replaces. The ACM shall clearly indicate each of the tags on the compliance documentation. To generate the proposed design, the ACM shall run the calculations using the surfaces and systems that represent the building when the additions and/or alterations are complete. This includes building features that are tagged as existing, altered and added. Features that are being deleted are not included in the proposed design.

When modeling an existing building, the ACM shall allow the use of the default assumptions specified in Table R3-11 for modeling the existing structure according to the vintage of the existing building. If the user enters higher U-factors, higher F-factors, higher SHGCs, lower efficiencies, or lower energy factors than the vintage defaults from Table R3-11 for the existing building's *Proposed Design*, the ACM shall report such values as special features in the *Special Features and Modeling Assumptions* listings.

Standard Design. Establishing the standard design for e+ad+al approach requires use of the tags entered by the user and, in some circumstances if there are alterations that involve fenestration, a simulation to determine if prescriptive shading requirements are met or exceeded. The resulting e+ad+al Standard Design is very different from the Standard Design for newly constructed buildings because it accounts for the energy use of the existing building and for altered features, and is dependent on whether altered features meet the prescriptive alteration requirements. The Standard Design is determined using the following rules:

- Existing features are included in the standard design
- Deleted features are included in the standard design
- Added features are assigned standard design values in the same manner as for an addition alone, as described above
- Altered features are modeled in the standard design as follows:

  General Approach. Each altered feature is compared to the prescriptive requirements in Section 152(b)1. Fenestration shading and area have additional modeling requirements described below:

- o If the altered feature meets or exceeds the prescriptive alteration requirements the Standard Design is the unaltered existing feature (note that the prescriptive alteration requirements are the mandatory requirements for all altered components plus additional prescriptive requirements for altered fenestration, HVAC equipment (refrigerant charge measurement or TXV), and ducts);
- o Otherwise, the Standard Design is the prescriptive alteration requirement (i.e., the mandatory requirement for altered components other than altered fenestration, HVAC equipment and ducts, which have additional prescriptive requirements beyond the mandatory requirements)

Fenestration Shading. Determining whether the prescriptive alteration requirement for fenestration shading is met may require an annual TDV energy simulation as follows:

- o For climate zones with an SHGC requirement, where the annual TDV energy for the combination of the proposed altered fenestration and the shading of that altered fenestration by existing overhangs or sidefins is less than or equal to the annual TDV energy due to the prescriptive alteration fenestration shading requirement with no shading from overhangs or sidefins, the Standard Design is the unaltered existing feature (existing fenestration products plus existing shading). Otherwise, the Standard Design is the prescriptive alteration requirement.
- o For climate zones without an SHGC requirement, the Standard Design is the unaltered existing feature (existing fenestration products plus existing shading).

Fenestration Area. The Standard Design surfaces and areas for the existing plus alteration (fenestration area in an addition is not included in this section) is determined as follows:

- o If no fenestration area is being added, then the fenestration surfaces in the Standard Design are the existing fenestration surfaces.
- o If fenestration area is being added and the existing fenestration area is less than or equal to 20% of the existing floor area and the combination of the existing plus added fenestration is less than or equal to 20% of the existing floor area, then the fenestration surfaces in the Standard Design are the existing fenestration surfaces plus the added fenestration surfaces.
- o If fenestration area is being added and the existing fenestration area is less than or equal to 20% of the existing floor area and the combination of the existing plus added fenestration is greater than 20% of the existing floor area, then the fenestration area in the Standard Design is 20% of the existing floor area. The fenestration surfaces in the Standard Design are the existing fenestration surfaces plus the added fenestration surfaces with the added surface areas scaled so that the total area of existing plus added fenestration surfaces equals 20% of the existing floor area. For example, if the existing floor area is 2,000 square feet, the existing fenestration is 300 square feet, and the added fenestration is 200 square feet, the scaling factor applied to each added fenestration surface would be:

Equation R3-2

$$\begin{aligned} \text{ScalingFactor} &= \frac{(0.20\text{xExistingCFA}) - (\text{ExistingFenArea})}{\text{AddedFenArea}} \\ &= \frac{(0.20 \times 2000) - 300}{200} = 0.50 \end{aligned}$$

Thus, the square footage of each of the new fenestration surfaces would be scaled by a factor of 0.50 to determine the Standard Design.

- o Otherwise, if fenestration area is being added and the existing fenestration area is greater than 20% of the existing floor area, then the fenestration surfaces in the Standard Design are the existing fenestration surfaces.

The resulting Standard Design inputs are run as a single simulation and the results are compared to the Proposed Design. The energy use of the e+ad+al Proposed Design shall use equal or less energy than the e+ad+al Standard Design.

Conceptually, the e+ad+al approach can be described as follows where the right hand side term is calculated in a single simulation:

Equation R3-3 $$EU_{e+ad+al} \leq EU_e + EB_{ad} + EB_{al}$$

Where

$EU_{e+ad+al}$ = the Proposed Design energy use of the existing building with all additions and alterations completed

EU_e = the energy use for the unaltered portion of the existing building

EB_{ad} = the Standard Design energy use for the addition alone

EB_{al} = the Standard Design energy use of the altered features (= energy use of the unaltered existing feature when the prescriptive alteration requirements, including mandatory requirements, are met or energy use of the prescriptive alteration requirements when the prescriptive alteration requirements are not met).

3.8.4 Duct Sealing in Additions and Alterations

Section 152(a)1 establishes prescriptive requirements for duct sealing in additions and Sections 152(b)1.D. and 152(b)1.E. establish prescriptive requirements for duct sealing and duct insulation for installation of new and replacement duct systems and duct sealing for installation of new and replacement space conditioning equipment. Table R4-13 provides Duct Leakage Factors for modeling of sealed and tested new duct systems, sealed and tested existing duct systems, and untested duct systems built prior to and after June 1, 2001. Appendix RC provides procedures for duct leakage testing and Table RC-2 provides duct leakage tests and leakage criteria for sealed and tested new duct systems and sealed and tested existing duct systems. These requirements, factors, procedures, tests and criteria apply to performance compliance for duct sealing in Additions and Alterations.

Condition	*Proposed Design*	*Standard Design*
Additions Served by Entirely New Duct Systems	The Proposed Design shall be either sealed and tested new duct systems or untested duct systems.	The Standard Design shall be sealed and tested new duct systems.
Additions Served by Extensions of Existing Duct Systems	The Proposed Design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems in homes built after June 1, 2001; or 4) untested duct systems in homes built prior to June 1, 2001.	The Standard Design shall be sealed and tested existing duct systems.
Alterations with Prescriptive Duct Sealing Requirements when Entirely New Duct Systems are Installed	The Proposed Design shall be either 1) sealed and tested new duct systems; 2) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.	The Prescriptive Alteration Requirement is sealed and tested new duct systems. Determine the Standard Design by the Standard Design rules in Section 3.8.3.

Condition	*Proposed Design*	*Standard Design*
Alterations with Prescriptive Duct Sealing Requirements when Existing Duct Systems are extended or replaced or when new or replacement air conditioners are installed	The Proposed Design shall be either 1) sealed and tested new duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.	Prescriptive Alteration Requirement is sealed and tested existing duct systems. Determine the Standard Design by the Standard Design rules in Section 3.8.3.
Alterations for which Prescriptive Duct Sealing Requirements do not apply	The Proposed Design shall be either 1) sealed and tested new duct systems, if the new duct system or the total combined existing plus new duct system meets the leakage requirements for tested and sealed new duct systems; 2) sealed and tested existing duct systems, if the total combined existing plus new duct system meets the leakage requirements for tested and sealed existing duct systems; 3) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.	The Standard Design shall be either 1) untested duct systems built after June 1, 2001; or 3) untested duct systems in homes built prior to June 1, 2001.

Table R3-11 – Default Assumptions for Existing Buildings

	Default Assumptions for Year Built (Vintage)							
Conservation Measure	**Before 1978**	**1978 to 1983**	**1984 to 1991**	**1992 to 1998**	**1999 - 2000**	**2001-2003**	**2004-2005**	**2006 and Later**
INSULATION U-FACTOR								
Roof	0.079	0.049	0.049	0.049	0.049	0.049	0.049	0.049
Wall	0.356	0.110	0.110	0.102	0.102	0.102	0.102	0.102
Raised Floor –CrawlSp	0.099	0.099	0.099	0.046	0.046	0.046	0.046	0.046
Raised Floor-No CrawlSp	0.238	0.238	0.238	0.064	0.064	0.064	0.064	0.064
Slab Edge F-factor =	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Ducts	R-2.1	R-2.1	R-2.1	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
LEAKAGE								
Building (SLA)	4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Duct Leakage Factor (See Table 4-13)	0.86	0.86	0.86	0.86	0.86	0.89	0.89	0.89
FENESTRATION								
U-factor	Use Table 116-A - Title 24, Part 6, Section 116 for all Vintages							
SHGC	Use Table 116-B - Title 24, Part 6, Section 116 for all Vintages							
Shading Dev.	Use Table R3-7 for all Vintages							
SPACE HEATING EFFICIENCY								
Gas Furnace (Central) AFUE	0.75	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Gas Heater (Room) AFUE	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Heat Pump HSPF	5.6	5.6	6.6	6.6	6.8	6.8	6.8	7.4
Electric Resistance HSPF	3.413	3.413	3.413	3.413	3.413	3.413	3.413	3.413
SPACE COOLING EFFICIENCY								
All Types, SEER	8.0	8.0	8.9	9.7	9.7	9.7	9.7	12.0
WATER HEATING								
Energy Factor	0.525	0.525	0.525	0.525	0.58	0.58	0.575	0.575
Rated Input, MBH	28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0

4. Required Modeling Assumptions and Algorithms

Most of the modeling assumptions and algorithms about building operation and climate are either fixed or restricted when an ACM is used for compliance.

All approved ACMs shall include and automatically use all the appropriate fixed and restricted inputs and calculation methods with no special entry required by the user. Users may not override the fixed inputs when the ACM is used for compliance calculations, nor are users allowed to go beyond the limitations of the restricted assumptions.

The fixed and restricted modeling assumptions apply to both the *Standard Design* run and to the *Proposed Design* run. The *standard* fixed and restricted modeling assumptions always apply to the *Standard Design* run and are the *default* for the *Proposed Design*. In some cases, the CEC has approved *alternate* fixed and restricted modeling assumptions that may be used in the *Proposed Design* run. When the assumptions differ between the *Standard Design* and the *Proposed Design*, this is called to the attention of the reader in this chapter. The alternate modeling assumptions may only be used when the *Proposed Design* run has a special building feature (e.g. zonal control) that is recognized for credit, and the ACM has been approved with this modeling capability. The modeling of such building features for compliance purposes shall always be documented in the *Special Features and Modeling Assumptions* listings on the Certificate of Compliance.

While this manual describes the algorithms and calculation methods used by the reference method, an ACM may use alternative algorithms to calculate the energy use of low-rise residential buildings provided that the algorithms are used consistently for the *Standard Design* and the *Proposed Design* and provided that the ACM passes the applicable tests described in Chapters 5 and 6.

4.1 General Modeling Assumptions

4.1.1 Weather Data

All ACMs shall use standard hourly weather data for compliance runs. The same hourly weather data and weather data format shall be used for both the *Standard Design* and the *Proposed Design* calculations.

ACM Joint Appendix II contains information about how to obtain the official CEC weather data. There are 16 climate zones with a complete year of 8,760 hourly weather records. Each climate zone is represented by a particular city.

Time Dependent Valuation (TDV) energy is the parameter used to compare the energy consumption of proposed designs to energy budgets. TDV replaces the source energy multipliers of one for natural gas and 3 for electric. TDV is explained in ACM Joint Appendix III in more detail.

4.1.2 Ground Reflectivity

ACMs shall assume that the ground surrounding residential buildings has a reflectivity of 20 percent in both summer and winter. This applies to both the *Standard Design* and *Proposed Design*.

4.1.3 Thermostats

The *standard* thermostat settings are shown in Table R4-1 below. The values for the “Whole House” apply to the *Standard Design* run and are the default for the *Proposed Design* run. See the explanation later in this section regarding the values for Zonal Control.

Table R4-1 – Hourly Thermostat Set Points

	Whole House		Zonal Control Living Areas		Zonal Control Sleeping Areas		
Hour	Heating	Cooling	Heating	Cooling	Heating	Cooling	Venting
1	65	78	65	83	65	78	Off
2	65	78	65	83	65	78	Off
3	65	78	65	83	65	78	Off
4	65	78	65	83	65	78	Off
5	65	78	65	83	65	78	Off
6	65	78	65	83	65	78	68
7	65	78	65	83	65	78	68
8	68	83	68	83	68	83	68
9	68	83	68	83	65	83	68
10	68	83	68	83	65	83	68
11	68	83	68	83	65	83	68
12	68	83	68	83	65	83	68
13	68	83	68	83	65	83	68
14	68	82	68	82	65	83	68
15	68	81	68	81	65	83	68
16	68	80	68	80	65	83	68
17	68	79	68	79	65	83	68
18	68	78	68	78	65	83	68
19	68	78	68	78	65	83	68
20	68	78	68	78	65	83	68
21	68	78	68	78	65	83	68
22	68	78	68	78	68	78	68
23	68	78	68	78	68	78	68
24	65	78	65	83	65	78	Off

Determining Heating Mode vs. Cooling Mode. When the building is in the heating mode, the heating setpoints for each hour are set to the “Heating” values in Table R4-1, the cooling setpoint is set to a constant 78°F and the ventilation setpoint is set to a constant 77°F. When the building is in the cooling mode, the “Cooling” values are used. The heating setpoint is set to a constant 60°F, and the cooling and venting setpoints are set to the values in Table R4-1.

The state of the building's conditioning mode is dependent upon the outdoor temperature averaged over hours 1 through 24 of day 8 through day 2 prior to the current day (e.g., if the current day is June 21, the mode is based on the average temperature for June 13 through 20). The ACM shall calculate and update daily this 7-day running average of outdoor air temperature. When this running average temperature is equal to or less than 60°F the building shall be set in a heating mode and all the thermostat setpoints for the heating mode shall apply. When the running average is greater than 60°F the building shall be set to be in a cooling mode and the cooling mode setpoints shall apply.

Zonal Control: An optional capability, described in Chapter 6, allows alternative thermostat schedules to be used for the *Proposed Design* run when the HVAC system meets the requirements for zonal control. With zonal control, the building is divided into sleeping and living areas and a separate schedule is used for each area. If the user selects this option the ACM shall use the appropriate alternative schedules based on the user’s designations for sleeping and living zones and shall automatically report the use of this optional capability in the *Special*

Features and Modeling Assumptions listings in the CF1-R. The setpoints for zonal control are also shown in Table R4-1.

Setback Thermostat Exceptions. Certain types of heating and/or cooling equipment are excepted from the mandatory requirement for setback thermostats, including wall furnaces and through-the-wall heat pumps. If setback thermostats are not installed, then the ACM shall model the *Proposed Design* with the standard thermostat schedule, except that the heating mode setback setpoint shall be 66°F. In cases where setback thermostats are not mandatory but nonetheless are installed by the builder, the ACM shall model the *Proposed Design* using the standard heating setback setpoint of 65°F. The *Standard Design* always assumes the setback schedule shown in Table R4-1.

4.1.4 Internal Gains

Basic Allocation

Internal gain from lights, appliances, people and other sources shall be set to 20,000 Btu/day for each dwelling unit plus 15 Btu/day for each square foot of conditioned floor area (CFA) as shown in Equation R4-1.

Equation R4-1
$$IntGain_{total} = (20{,}000 \times N) + \left(15 \times \sum_{i=1}^{N} CFA_i\right)$$

Where

N= Number of dwelling units

CFA_i= Conditioned Floor Area of i^{th} dwelling unit

Zonal Control

For zonal control, an optional modeling capability, the internal gains are split between the living areas and the sleeping areas as indicated in the following equations. The 20,000 Btu/day fixed component is assigned 100% to the living areas and the 15 Btu/ft² component is allocated according to floor area. See Equation R4-2 and Equation R4-3.

Equation R4-2
$$IntGain_{Living} = 15 \times CFA_{Living}$$

Equation R4-3
$$IntGain_{Sleeping} = 15 \times CFA_{Sleeping}$$

Additions

For addition-alone compliance (single-zone), the internal gains are apportioned according to the fractional conditioned floor area, referred to as the Fractional Dwelling Unit (FDU). For zone j, the internal gain is determined by Equation R4-4.

Equation R4-4
$$IntGainZone_j = IntGain_{tot} \times FDU_j$$

where

FDU_j = Fractional Dwelling Unit of j^{th} zone, calculated from Equation R4-5

Equation R4-5

$$FDU_j = \frac{CFA_j}{CFA_{total}}$$

Building additions may be modeled in conjunction with the existing dwelling or modeled separately (see Chapter 6). When modeled together the number of dwelling units for the proposed dwelling ($NDU_{proposed}$) remains equal to the number of dwelling units for the existing structure ($NDU_{existing}$), while the conditioned floor area ($CFA_{proposed}$) is increased to include the contribution of the addition ($CFA_{addition}$). When modeled separately, the internal gain of the addition ($IntGain_{addition}$)is based on the value of the addition's fractional dwelling unit ($FDU_{addition}$), as expressed in Equation R4-6 and Equation R4-7.

Equation R4-6

$$IntGain_{addition} = IntGain_{total} \times FDU_{addition}$$

Equation R4-7

$$FDU_{addition} = \frac{CFA_{addition}}{CFA_{existing} + CFA_{addition}}$$

Hourly Schedules

The standard hourly internal gain schedule is shown in Table R4-2. “Hour one” is between midnight and 1:00 am. The whole building schedule shall always be used for the *Standard Design* run. The whole building is also used for the *Proposed Design* unless the *Proposed Design* has zonal control. For zonal control, the Living Areas schedule is used for the living areas and the Sleeping Areas schedule is used for sleeping areas.

Table R4-2 – Hourly Internal Gain Schedules

Hour	Percent of Daily Total Internal Gains (%)		
	Whole House	Living Areas	Sleeping Areas
1	2.40	1.61	4.38
2	2.20	1.48	4.02
3	2.10	1.14	4.50
4	2.10	1.13	4.50
5	2.10	1.21	4.32
6	2.60	1.46	5.46
7	3.80	2.77	6.39
8	5.90	5.30	7.40
9	5.60	6.33	3.76
10	6.00	6.86	3.85
11	5.90	6.38	4.70
12	4.60	5.00	3.61
13	4.50	4.84	3.65
14	3.00	3.15	2.63
15	2.80	2.94	2.46
16	3.10	3.41	2.32
17	5.70	6.19	4.47
18	6.40	7.18	4.45
19	6.40	7.24	4.29
20	5.20	5.96	3.30
21	5.00	5.49	3.75
22	5.50	6.20	3.75
23	4.40	4.38	4.45
24	2.70	2.35	3.59
Total	100.00	100.00	100.00

Seasonal Adjustments

Daily internal gain shall be modified each month according to the multipliers shown in Table R4-3. These multipliers are derived from the number of daylight hours for each month.

Table R4-3 – Seasonal Internal Gain Multipliers

Month	Multiplier	Month	Multiplier	Month	Multiplier
Jan	1.19	May	0.84	Sep	0.98
Feb	1.11	Jun	0.80	Oct	1.07
Mar	1.02	Jul	0.82	Nov	1.16
Apr	0.93	Aug	0.88	Dec	1.21

4.2 Heat Gains and Losses Through Opaque Surfaces

4.2.1 Radiant Barriers

Algorithm

The benefits of radiant barriers are modeled in two ways. First, the ceiling U-factor is modified for each season (heating mode and cooling mode) to account for reduced heat gain (attics are not modeled as separate unconditioned thermal zones in residential ACMs). Second, the seasonal temperatures for attics are lower with radiant barriers, which results in better HVAC distribution efficiency for ducts located in the attic. See the algorithms for HVAC air distribution ducts for more details.

When the building is in a heating mode, (see Section 4.1.3), Equation R4-8 provides the U-factor modifier due to the presence of a radiant barrier. When the building is in a cooling mode, Equation R4-9 is used. To determine the U-factor for a ceiling with a radiant barrier, multiply the U-factor of the ceiling assembly located beneath a radiant barrier times the U-factor modifier. These modifiers may only be used for installed insulation greater than R-8, otherwise the modifer is 1.00.

Equation R4-8 $$UfacMod_{heating} = (-11.404 \text{ x } U^2) + (0.21737 \text{ x } U) + 0.92661$$

Equation R4-9 $$UfacMod_{cooling} = (-58.511 \text{ x } U^2) + (3.22249 \text{ x } U) + 0.64768$$

Eligibility Criteria

Radiant barriers shall meet specific eligibility and installation criteria to be modeled by any ACM and receive energy credit for compliance with the energy efficiency standards for low-rise residential buildings.

- The emittance of the radiant barrier shall be less than or equal to 0.05 as tested in accordance with ASTM C-1371 or ASTM E408.
- Installation shall conform to ASTM C1158 (*Standard Practice for Installation and Use of Radiant Barrier Systems (RBS) in Building Construction*), ASTM C727 (*Standard Practice for Installation and Use of Reflective Insulation in Building Constructions*), ASTM C1313 (*Standard Specification for Sheet Radiant Barriers for Building Construction Applications*), and ASTM C1224 (*Standard Specification for Reflective Insulation for Building Applications*), and the radiant barrier shall be securely installed in a permanent manner with the shiny side facing down toward the interior of the building (ceiling or attic floor). Moreover, radiant barriers shall be installed at the top chords of the roof truss/rafters in ***any*** of the following methods:
  1. Draped over the truss/rafter (the top chords) before the upper roof decking is installed.
  2. Spanning between the truss/rafters (top chords) and secured (stapled) to each side.
  3. Secured (stapled) to the bottom surface of the truss/rafter (top chord). A minimum air space shall be maintained between the top surface of the radiant barrier and roof decking of not less than 1.5 inches at the center of the truss/rafter span.
  4. Attached [laminated] directly to the underside of the roof decking. The radiant barrier shall be laminated and perforated by the manufacturer to allow moisture/vapor transfer through the roof deck.

  In addition, the radiant barrier shall be installed to cover all gable end walls and other vertical surfaces in the attic.
- The attic shall be ventilated to:
  1. Conform to the radiant barrier manufacturer's instructions.

2. Provide a minimum free ventilation area of not less than one square foot of vent area for each 150 square feet of attic floor area.

3. Provide no less than 30 percent upper vents.

Ridge vents or gable end vents are recommended to achieve the best performance. The material should be cut to allow for full airflow to the venting.

- The radiant barrier (except for radiant barriers laminated directly to the roof deck) shall be installed to have a minimum gap of 3.5 inches between the bottom of the radiant barrier and the top of the ceiling insulation to allow ventilation air to flow between the roof decking and the top surface of the radiant barrier have a minimum of six (6) inches (measured horizontally) left at the roof peak to allow hot air to escape from the air space between the roof decking and the top surface of the radiant barrier.
- When installed in enclosed rafter spaces where ceilings are applied directly to the underside of roof rafters, a minimum air space of 1 inch shall be provided between the radiant barrier and the top of the ceiling insulation, and ventilation shall be provided for every rafter space. Vents shall be provided at both the upper and lower ends of the enclosed rafter space.
- The product shall meet all requirements for California certified insulation materials [radiant barriers] of the Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, as specified by CCR, Title 24, Part 12, Chapter 12-13, Standards for Insulating Material.
- The use of a radiant barrier shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and described in detail in the ACM Compliance Supplement.

4.2.2 Cool Roofs

Algorithm

Cool roofs are modeled to have an impact equal to the cooling savings for radiant barriers. The calculations for cool roofs are the same as radiant barriers, except that $UfacMod_{heating}$ (see Equation R4-8) is assigned a value of 1.00. In the event that both a cool roof and radiant barrier are specified, there is no credit for the cool roof.

Eligibility Criteria

Cool roofs shall meet specific eligibility and installation criteria to receive credit for compliance. The solar reflectance shall be 0.4 or higher for tile roofs or 0.7 or higher for other roof materials; and the emittance shall be 0.75 or higher. Liquid applied cool roof products shall meet the requirements of Section 118(i)3 of the standards. All products qualifying for this credit shall be rated and labeled by the Cool Roof Rating Council in accord with Section 10-113 of the standards. The use of a cool roof shall be listed in the *Special Features and Modeling Assumptions* listings of the CF-1R and described in detail in the ACM Compliance Supplement.

4.2.3 R-Value/U-factor Determinations

Thermal resistances (R-values) and thermal transmittance values (U-factors) shall be determined from ACM Joint Appendix IV. Standard framed (wood and metal) walls with studs 16 in. on center shall be modeled to have 25% framing, and standard framed walls with studs located at 24 in. centers shall be modeled to have 22% framing.

Degree of Precision: The total R-value shall be entered, stored, displayed, and calculated to at least three significant figures, or, alternatively to two decimal places, and the total U-factor to two significant figures or three decimal places whichever is more precise.

Data from ACM Joint Appendix IV shall be used in compliance calculations unless the Energy Commission approves alternate values through the exceptional methods process. Appendix IV also includes pre-calculated assemblies that meet the default U-factors using a combination of batt and rigid insulation. Steel framing assemblies are also included. Appendix IV has R-values for common materials; information on a variety of masonry wall assemblies; and other data useful in determining the U-factor of an assembly.

4.2.4 Insulation Installation Quality

Compliance credit is available for low-rise residential buildings if field verification is performed to ensure that quality insulation and air barrier installation procedures are followed (see Appendix RH). All newly insulated opaque surfaces in a building must be field verified to receive this credit. Compliance reports and user interfaces shall identify the building as having either *Standard* or *Improved* insulation installation quality. As discussed in Chapter 3, the *Standard Design* shall have standard insulation installation quality. Approved ACMs must be able to model both *Standard* and *Improved* insulation installation quality (see Table R4-4).

Table R4-4 – Modeling Rules for insulation installation Quality

		insulation installation Quality	
Component	Mode	Standard	Improved
Walls	Both	Increase heat gains and losses by 19%, i.e., multiply all wall U-factors by 1.19.	Increase heat gains and losses by 5%, i.e., multiply all wall U-factors by 1.05.
Ceilings/Roofs	Heating	Add 0.02 times the area to the UA of each ceiling surface i.e., add 0.02 to the U-factor.	Add 0.01 times the area to the UA of each ceiling surface i.e., add 0.01 to the U-factor.
	Cooling	Add 0.005 times the area to the UA of each ceiling surface i.e., add 0.005 to the U-factor.	Add 0.002 times the area to the UA of each ceiling surface i.e., add 0.002 to the U-factor.

When credit is taken for Improved insulation installation quality, the *Field Verification and Diagnostic Testing* section of the CF-1R shall show that field verification is required (see Chapter 2) and the Installation Certificate (CF-6R) and the Field Verification and Diagnostic Testing Certificate (CF-4R) must be completed and signed by the installer and HERS Rater, respectively.

4.2.5 Perimeters of Slab Floors and Carpeted Slabs

For *Standard and Proposed Designs* all ACMs shall use slab edge F2 values assuming that 20% of the slab floor perimeter is exposed to the conditioned air and 80% of the slab floor perimeter is carpeted or covered with an R-2 insulating layer between the slab and the conditioned air. See ACM Joint Appendix IV.

The monthly ground temperatures shown in Table R4-5 shall be used as the exterior temperature when calculating slab edge heat loss.

Table R4-5 – Monthly and Annual Average Ground Temperatures

Climate Zone	Month J	F	M	A	M	J	J	A	S	O	N	D	Annual Average
1	52.2	51.5	51.4	51.8	53.1	54.5	55.6	56.4	56.4	55.8	54.7	53.4	53.9
2	53.3	51.5	51.4	52.2	55.6	58.9	61.8	63.6	63.8	62.3	59.5	56.3	57.5
3	55.1	54.1	54.0	54.5	56.5	58.5	60.3	61.4	61.5	60.6	58.9	56.9	57.7
4	55.5	54.0	53.9	54.6	57.5	60.3	62.8	64.3	64.5	63.2	60.8	58.0	59.1
5	55.7	54.8	54.7	55.2	56.9	58.7	60.2	61.1	61.2	60.4	59.0	57.3	57.9
6	59.1	58.1	58.0	58.5	60.4	62.4	64.0	65.1	65.2	64.3	62.7	60.8	61.6
7	60.1	59.1	59.0	59.5	61.5	63.4	65.2	66.2	66.3	65.5	63.8	61.9	62.6
8	60.0	58.8	58.7	59.2	61.6	63.9	66.0	67.3	67.4	66.3	64.3	62.1	63.0
9	60.5	59.1	59.0	59.7	62.2	64.8	67.1	68.5	68.6	67.5	65.3	62.8	63.8
10	59.4	57.6	57.4	58.3	61.8	65.2	68.2	70.1	70.2	68.7	65.8	62.4	63.8
11	54.9	52.4	52.2	53.4	58.2	63.0	67.2	69.8	70.0	67.9	63.8	59.2	61.0
12	54.6	52.5	52.3	53.3	57.3	61.3	64.8	67.0	67.2	65.4	62.0	58.1	59.7
13	57.5	54.7	54.5	55.8	61.0	66.2	70.6	73.5	73.7	71.4	67.0	62.0	64.0
14	54.2	51.2	51.0	52.4	58.2	63.9	68.8	72.0	72.2	69.7	64.8	59.3	61.5
15	66.8	64.0	63.8	65.1	70.4	75.8	80.4	83.3	83.6	81.2	76.7	71.5	73.6
16	44.4	41.8	41.6	42.8	47.7	52.6	56.8	59.5	59.7	57.5	53.4	48.7	50.5

4.2.6 Basement Modeling - Basement Walls and Floors

Below grade walls shall be modeled with no solar gains, i.e., absorptivity is zero. Below grade walls are modeled with three exterior conditions depending on whether the depth is shallow, medium, or deep. The temperature of the earth depends on the depth of the wall and is given in Table R4-6. Thermal resistance also shall be increased to account for earth near the construction (see Table R4-6).

Table R4-6 – Earth Temperatures for Modeling Basement Walls and Floors

Class	Depth	Assumed Temperature of the Earth	Thermal Resistance of Earth
Shallow Depth Walls	Up to 2 ft	Average air temperature for hours 1 through 24 of the 7 days beginning 8 days prior to the current day (days -8 through -2).	A thermal resistance with an R-value of 1.57 (hr.ft^2.^{o}F/Btu) is added to the outside of the below grade wall.
Medium Depth Walls	2+ to 6 ft	Exterior earth temperature is assumed to be the monthly average temperature from Table R4-5.	A thermal resistance with an R-value of 7.28 (hr.ft2.^{o}F/Btu) is added to the outside of the below grade wall.
Deep Walls	More than 6 ft	Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R4-5.	A thermal resistance with an R-value of 13.7 (hr.ft2.^{o}F/Btu) is added to the outside of the below grade wall.
Basement Floors	Any	Exterior earth temperature is used which is typical of deep ground. Use the annual average value from Table R4-5.	A thermal resistance with an R-value of 17.6 (hr.ft2.^{o}F/Btu) is added to the bottom of the basement floor.

4.3 Heat Gains and Losses through Fenestration

4.3.1 Fenestration Products

Information concerning fenestration products, specifically the default table for fenestration U-factors and the default table for fenestration SHGC values, is included in Section 116 of Title 24, Part 6.

4.3.2 Solar Gain

Solar gain through glazing shall be calculated using the methods documented in the *Algorithms and Assumptions Report, 1988*. However, solar gain through windows is reduced to 72 percent of the full solar gain and a algorithm is used to calculate the transmitted solar gain as a function of the angle of incidence on the glazing. The 0.72 multiplier is intended to compensate for exterior shading from landscaping, terrain, and adjacent buildings, as well as dirt and other window obstructions.

The equations used to calculate the solar heat gain through windows as a function of the angle of incidence are given below in the form of two multipliers: - G_{dir} - the ratio of the solar heat gain to the space relative to direct beam insolation at normal incidence, and G_{dif} - the ratio of solar heat gain to the space relative to the diffuse insolation on a horizontal surface. These ratios are unitless.

Equation R4-10 $$G_{dir} = SHGC_{fen} * Area * \left[fsunlit * CosI * P(CosI) + GrndFac \right]$$

and

Equation R4-11 $$G_{dif} = SHGC_{fen} * Area * DMSHGC * \left(vfSky + vfGrnd * GrndRf \right)$$

where

Equation R4-12 $$P(CosI) = C1 * CosI + C2 * Cos^2 I + C3 * Cos^3 I + C4 * Cos^4 I$$

Equation R4-13 $$GrndFac = vfGrnd \times CosG \times GrndRf \times DMSHGC$$

$SHGC_{fen}$ =	Fenestration Solar Heat Gain Coefficient at normal beam incidence - primary user input [unitless]
CosI =	The cosine of the angle of incidence of the direct beam insolation on the window. [unitless]
CosG =	The cosine of the angle of incidence of the direct beam insolation on the ground. [unitless]
DMSHGC =	Diffuse Multiplier for Solar Heat Gain Coefficient [unitless]
fsunlit =	Fraction of the window sunlit by direct beam at this hour [unitless]
C1, ...,C4 =	Polynomial coefficients for angular dependence (cosine of the angle of incidence) of solar heat gain - see Table R4-7.
vfSky =	View factor of window to sky [unitless]
vfGrnd =	View factor from window to ground [unitless]
GrndRf =	Ground Reflectance [unitless] = 0.20

Table R4-7 – Polynomial Coefficients for Angular Dependence

Glazing Type:	Single Pane (1 light)	More Than One Pane (2 or more lites)
$SHGC_{fen}$	0.860	0.695
C1	3.549794	1.881643
C2	-4.597536	1.014431
C3	2.432124	-4.009235-
C4	-0.384382	2.113160
DMSHGC	0.905814	0.828777

4.3.3 Interior and Exterior Shading

Draperies are assumed to be closed only for hours when the air conditioner operates. To approximate this affect during transitions between periods of operation and non-operation, ACMs may assume that the internal device remains closed for the hour following an hour of air conditioner operation. As soon as that hour passes, the internal shading device shall be opened unless the air conditioner continues to run. The internal device shall be either totally open or totally closed for any given hour.

External sunscreens are assumed to be in place all year, whether the building is in a heating or cooling mode.

The shading effects of overhangs, side fins and other fixed shading devices are determined hourly, based on the altitude and azimuth of the sun for that hour, the orientation of the fenestration, and the relative geometry of the fenestration and the fixed shading devices.

The standard assumptions for operation of interior shading devices and sunscreens shall apply to both the *Standard Design* and the *Proposed Design*.

4.3.4 Solar Heat Gain Coefficients

ACMs use two solar heat gain coefficient values: "$SHGC_{open}$ " and "$SHGC_{closed}$." "$SHGC_{open}$ " applies when the air conditioner is not in operation (off) and "$SHGC_{closed}$ " applies when the air conditioner is in operation. The ACM user shall not be allowed to enter values for $SHGC_{open}$ and $SHGC_{closed}$. The ACM shall automatically determine these values from the user's choices of exterior shading devices and from the assumption that vertical glazing has a drapery and non-vertical (skylight) glazing has no interior shading device.

There are a limited set of shading devices with fixed prescribed characteristics that are modeled in the performance approach. These devices and their associated fixed solar heat gain coefficients are listed in Table R3-5 and Table R3-7.

The formula for combining solar heat gain coefficients is:

Equation R4-14
$$SHGC_{comb} = \left[\left(0.2875 \times SHGC_{max}\right) + 0.75\right] \times SHGC_{min}$$

where

$SHGC_{comb}$ = the combined solar heat gain coefficient for a fenestration component and an attachment in series.

$SHGC_{max}$ = the larger of $SHGC_{fen}$ and $SHGC_{dev}$

$SHGC_{min}$ = the smaller of $SHGC_{fen}$ and $SHGC_{dev}$

where

$SHGC_{fen}$ = the solar heat gain coefficient of the fenestration which includes the window glazing, transparent films and coatings, and the window framing, dividers and muntins,

$SHGC_{dev}$ = the solar heat gain coefficient of the interior or exterior shading device when used with a metal-framed, single pane window.

For $SHGC_{closed}$, the combination SHGC, $SHGC_{fen+int}$, (the combined SHGC for the fenestration and the interior device) is calculated first and then the combination $SHGC_{fen+int+ext}$ is calculated to determine the overall $SHGC_{closed}$. $SHGC_{open}$ is determined from the combination of $SHGC_{fen}$ and $SHGC_{ext}$.

4.4 Thermal Mass

ACMs shall be capable of modeling thermal mass in buildings. Thermal mass has the ability to store heat and thus damp temperature fluctuations in the conditioned space. There are two types of thermal mass, *Light Mass* which reacts very quickly to absorb or release heat, and *Heavy Mass* which reacts more slowly. *Light Mass* is modeled in the same way for both the *Proposed Design* and the *Standard Design*. The modeled mass includes common elements such as framing, furniture, ½ in. gypsum board, and household appliances. Light mass is modeled through an input in the reference program called building heat capacity and is assumed to be fixed at 3.5 Btu/ºF-ft² of conditioned floor area for both the *Proposed Design* and the *Standard Design*. Other values may be used for unconditioned zones (see Chapter 6).

“Heavy” mass includes elements such as concrete slab floors, masonry walls, double gypsum board and other special mass elements. When the *Proposed Design* qualifies as a high mass building then each element of heavy mass is modeled in the *Proposed Design*, otherwise, the *Proposed Design* is modeled with the same heavy thermal mass as the *Standard Design*. See Chapter 3 for details on what qualifies as a high mass building. The default thermal mass for the *Proposed Design* and the fixed thermal mass for the *Standard Design* is based on 20% of the slab floor being exposed and 80% covered with carpet or casework. In addition 5% of the non-slab floor is exposed with a topping of 2 in. of concrete. ACM RB-2005 has procedures for quantifying the value of various types of thermal mass.

Solar Gain Targeting. Solar gains from windows or skylights shall not be targeted to mass elements within the conditioned space of the building. In the reference program, CALRES, all solar gain is targeted to the air or a combined air-and lightweight, high surface area mass node within the building. This modeling assumption is used in both the *Standard Design* run and the *Proposed Design* run, except for sunspaces where the user has flexibility in targeting solar gains subject to certain constraints. Sunspace modeling is an optional capability discussed in Chapter 6.

Unconditioned Sunspaces. For compliance purposes, when glazing surfaces enclose unconditioned spaces, such as sunspaces, the user is allowed to target all but 25% of the solar gains from these surfaces to *Heavy* mass elements located within the unconditioned space. Unassigned solar gain is targeted to the air or the combined air/lightweight mass or to high surface area lightweight mass in the unconditioned space. At least 25% of the solar gain from any sunspace fenestration surface shall be targeted to high surface area lightweight mass and/or the air. At most 60% of the solar gain may be targeted to the slab floor of a sunspace, especially in the summer. For compliance purposes, an ACM shall automatically enforce these limits and inform the user of any attempt to exceed these limits.

4.5 Infiltration and Natural Ventilation

4.5.1 Infiltration/Ventilation

The reference method uses the effective leakage area method for calculating infiltration in conditioned zones. Calculations shall use Shielding Class 4 as defined in the 2001 *ASHRAE Handbook of Fundamentals*.

Default Specific Leakage Area. The default specific leakage area (SLA) is 4.9 for designs with ducted HVAC systems and 3.8 for non-ducted HVAC systems. The default is always used for the *Standard Design*. The *Proposed Design* may use an alternate value, but only with diagnostic testing. The specific leakage area (SLA) is the ratio of the effective leakage area to floor area in consistent units. The value is then increased by 10,000 to make the number more manageable. If the effective leakage area (ELA) is known in inches, then the SLA may be calculated with Equation R4-15.

Equation R4-15 $$SLA = \left(\frac{ELA}{CFA}\right)\left(\frac{ft^2}{144in^2}\right)(10000) = \left(\frac{ELA}{CFA}\right)69.444$$

where

ELA = Effective leakage area in square inches

CFA = Conditioned floor area (ft^2)

SLA = Specific leakage area (unitless)

Minimum Outside Air. For both the *Standard Design* and the *Proposed Design*, ACMs shall assume that occupants will open the windows if the air becomes stagnant. When natural ventilation, infiltration, and mechanical ventilation fall below a threshold value of 0.35 air changes per hour (ACH) , the occupants are assumed to open the windows at the beginning of the next hour sufficient to provide a combination of infiltration and ventilation equal to 0.35 ACH for an eight foot high ceiling. The windows are assumed to remain partially open to provide a minimum of 0.35 ACH as long as the previous hour's infiltration and mechanical ventilation rate is below the threshold.

Effective Leakage Area (ELA) Method. The Effective Leakage Area (ELA) method of calculating infiltration for conditioned zones is documented below and in Chapter 26 of the 2001 ASHRAE Handbook of Fundamentals. The ELA for the *Standard Design* and for the default values for the *Proposed Design* (if diagnostic tests are not used), is calculated from Equation R4-15. The energy load on the conditioned space from infiltration heat gains or losses are calculated as follows.

Equation R4-16 $$CFM_{infil} = ELA \times \sqrt{A \times \Delta T_2 + B \times V^2}$$

Equation R4-17 $$CFM_{infil+unbalfan} = \sqrt{CFM_{infil}^2 + MECH_{unbal}^2}$$

Equation R4-18 $$CFM_{infil+totfan} = CFM_{infil+unbalfan} + MECH_{bal}$$

The volumetric airflow (cfm) due to natural ventilation is derived from the natural ventilation cooling for the hour:

Equation R4-19 $$CFM_{natv} = \frac{Q_{natv}}{1.08 \times \Delta T_1}$$

The total ventilation and infiltration (in cfm) including indoor air quality window operation is:

Equation R4-20 $$CFM_{total} = CFM_{natv} + CFM_{infil+totfan} + CFM_{iaq}$$

The value of CFM_{iaq} depends on the sum of CFM_{natv} and $CFM_{infil+totfan}$ from the previous time step:

When

Equation R4-21 $$CFM_{natv} + CFM_{infil+totfan} < \frac{(AFT \times CFA)}{7.5}$$

then

Equation R4-22
$$CFM_{iaq} = \frac{(0.35 \times CFA)}{7.5}$$

otherwise

Equation R4-23
$$CFM_{iaq} = 0.000$$

where

CFA = the total conditioned floor area of the residence

AFT = 0.18 for Climate Zones 2 through 15 inclusive, and;

AFT = 0.25 for Climate Zones 1 and 16.

When the windows are opened they provide an overall ventilation rate equal to 0.35 air changes per hour for a residence of the same floor area but with eight foot high ceilings. CFM_{iaq} simulates the opening of windows to achieve an acceptable indoor air quality by the occupants when ventilation and infiltration from other sources does not provide an adequate quantity of outdoor air to dilute pollutants and refresh the indoor air.

The energy load on the conditioned space from all infiltration and ventilation heat gains or losses is calculated as follows:

Equation R4-24
$$Q_{total} = 1.08 \times CFM_{total} \times \Delta T_1$$

where

Q_{total} = Energy from ventilation and infiltration for current hour (Btu)

CFM_{infil} = Infiltration in cubic feet per minute (cfm)

$CFM_{infil+unbalfan}$ = combined infiltration and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$CFM_{infil+totfan}$ = infiltration plus the balanced and unbalanced mechanical ventilation in cubic feet per minute (cfm)

$MECH_{bal}$ = the balanced mechanical ventilation in cfm. This value is the smaller of the total supply fan cfm and the total exhaust fan cfm.

$MECH_{unbal}$ = the unbalanced mechanical ventilation in cfm. This value is derived from the absolute value of the difference between the total supply fan cfm and the total exhaust fan cfm.

1.08 = conversion factor in (Btu-min)/(hr-ft^3-°F)

ΔT_1 = difference between indoor and outdoor temperature for current hour (°F)

ΔT_2 = difference between indoor and outdoor temperature for previous hour (°F)

A = stack coefficient, (cfm^2/in^4/ F)

B = wind coefficient, (cfm^2/in^4/mph^2)

V = average wind speed for current hour (mph)

ELA = effective leakage area (in^2), measured or calculated using Equation R4-25.

The stack (A) and wind (B) coefficients to be used are shown in Table R4-8.

Table R4-8 – Infiltration Coefficients

Coefficient	*One Floor*	*Two Floors*	*Three Floors*
A (stack)	0.0156	0.0313	0.0471
B (wind) (Shielding Class 4)	0.0039	0.0051	0.0060

The ELA is calculated from the SLA as follows:

Equation R4-25
$$ELA = CFA \times SLA \times \left(\frac{144in^2}{1ft^2}\right) \times \left(\frac{1}{10{,}000}\right)$$

where

CFA = conditioned floor area (ft^2)

SLA = specific leakage area (ft^2/ft^2)

ELA = effective leakage area (in^2)

Alternatively, ELA and SLA may be determined from blower door measurements:

Equation R4-26
$$ELA = 0.055 \times CFM50_H$$

where

$CFM50_H$ = the measured airflow in cubic feet per minute at 50 pascals for the dwelling with air distribution registers unsealed.

Substituting Equation R4-26 into Equation R4-15 gives the relationship of the measured airflow rate to SLA:

Equation R4-27
$$SLA = 3.819 \times \frac{CFM50_H}{CFA}$$

Reduced Infiltration. ACM users may take credit for reduced infiltration (with mechanical ventilation when it is required) for low-rise, single-family dwellings when verified by on-site diagnostic testing. While credit is offered for reduced infiltration, the model also assumes that dwelling occupants will open windows when natural ventilation and infiltration do not provide a minimum of 0.35 ACH.

The Effective Leakage Area (ELA) of the dwelling may be reduced and the algorithm will result in less energy use due to infiltration unless windows are opened for ventilation. Lower ELAs will result in windows being opened more frequently and at some point energy use may increase. Air quality ventilation may also be added and if this ventilation plus infiltration and cooling ventilation provides adequate air exchange, window ventilation will no longer occur or will occur very infrequently. The energy use of both ventilation exhaust fans and ventilation supply fans shall be entered. These ventilation fans are assumed to operate continuously and the energy use of these fans shall be included as energy use in the *Proposed Design*. Both reduced ELA/SLA and ventilation fans are conditions which require field verification or diagnostic testing and shall be reported in the *Field Verification and Diagnostic Testing* listings on the Certificate of Compliance.

Controlled Ventilation Crawl Spaces and Sunspaces. Controlled ventilation crawl spaces (CVC) and sunspaces are modeled using the air changes per hour method. Modeling of CVC's and sunspaces are optional capabilities covered in Chapter 6. All optional capabilities that are used in the *Proposed Design* shall be reported in the *Special Features and Modeling Assumptions* listings on the Certificate of Compliance.

4.5.2 Natural Ventilation

The natural ventilation model is derived from the 2001 ASHRAE Handbook of Fundamentals. The model considers both wind effects and stack effects.

- Wind driven ventilation includes consideration of wind speed, prevailing direction and local obstructions, such as nearby buildings or hills.
- Stack driven ventilation includes consideration of the temperature difference between indoor air and outdoor air and the difference in elevation between the air inlet and the outlet.

For compliance purposes, the air outlet is always assumed to be 180 degrees or on the opposite side of the building from the air inlet and the inlet and outlet areas are assumed to be equal. The default inlet area (= outlet area) is five percent of the total window area.

Effective Ventilation Area (EVA)

Both wind and stack driven ventilation depends linearly on the effective ventilation area (EVA). The EVA is a function of the area of the air inlet and the area of the air outlet. For compliance purposes, the default area of air inlet and outlet are both equal to five per cent of the total window area, i.e., total ventilation area is 10% of the window area. For compliance purposes a different window opening area may be determined from the areas of different window opening types - fixed, sliders, and hinged windows. For compliance purposes, the air inlet and the air outlet are each equal to one-half of the *Free Ventilation Area*.

When the inlet area and outlet area are equal, the EVA is the same, i.e. equal to the inlet area or the outlet area. Hence for compliance purposes the EVA is equal to one-half of the *Free Ventilation Area.*

Stack Driven Ventilation

Stack driven ventilation results when there is an elevation difference between the inlet and the outlet, and when there is a temperature difference between indoor and outdoor conditions. See Equation R4-28.

Equation R4-28 $$CFM_S = 9.4 \times EVA \times EFF_S \times \sqrt{H \times \Delta T}$$

where

CFM_S = Airflow due to stack effects, cfm.

9.4 = Constant.

EVA = Effective ventilation area as discussed above, ft².

EFF_S = Stack effectiveness.

H = Center-to-center height difference between the air inlet and outlet.

ΔT = Indoor to outdoor temperature difference, °F.

For compliance purposes the stack effectiveness shall be set at 1.0. The ACM user shall not be permitted to alter this value.

Wind Driven Ventilation

The general equation for wind driven ventilation is shown below. This equation works in either a direction dependent implementation or a direction independent implementation, as explained later in the text.

Equation R4-29 $$CFM_w = EVA \times 88 \times MPH \times WF \times EFF_o \times EFF_d$$

where

CFM_W = Ventilation due to wind, cfm.

EVA = Effective vent area as discussed above, ft^2.

88 = A constant that converts wind speed in mph to wind speed in feet per minute.

MPH = Wind speed from the weather tape, mph.

WF = A multiplier that reduces local wind speed due to obstructions such as adjacent buildings. This input is fixed at 0.25 for compliance calculations.

EFF_o = Effectiveness of opening used to adjust for the location of the opening in the building, e.g. crawl space vents. This accounts for insect screens and/or other devices that may reduce the effectiveness of the ventilation opening. This input is also used to account for the location of ventilation area, e.g. the exceptional method for two-zone crawl space modeling provides for an alternative input for EFF_o. This input is fixed at 1.0 for compliance calculations other than crawlspace modeling.

EFF_d = Effectiveness that is related to the direction of the wind relative to the inlet surface for each hour. ASHRAE recommends that the effectiveness of the opening, EFF_d, be set to between 0.50 and 0.60 when the wind direction is perpendicular or normal to the inlet and outlet. A value of 0.25 to 0.35 is recommended for diagonal winds. When the wind direction is parallel to the surface of the inlet and outlet, EFF_d should be zero.

For compliance calculations, the orientation of the inlet and outlet is not considered. ACMs shall assume that the wind angle of incidence at 45 degrees on all windows and only the wind speed dependence is maintained. In this case, the product of EFF_o and EFF_d is equal to 0.28 regardless of the direction of the wind.

Combined Wind and Stack Effects

Stack effects and wind effects are calculated separately and added by quadrature, as shown below. This algorithm always adds the absolute value of the forces; that is, wind ventilation never cancels stack ventilation even though in reality this can happen.

Equation R4-30

$$CFM_t = \sqrt{CFM_w^2 + CFM_s^2}$$

where:

CFM_t = Total ventilation rate from both stack and wind effects, cfm.

CFM_W = Ventilation rate from wind effects, cfm.

CFM_S = Ventilation rate from stack effects, cfm.

Determination of Natural Ventilation for Cooling

The value of CFM_t described in Equation R4-30 above gives the maximum potential ventilation when the windows are open. Natural ventilation is available during cooling mode when there is venting shown in Table R4-1. The amount of natural ventilation used by ACMs for natural cooling is the lesser of this maximum potential amount available and the amount needed to drive the interior zone temperature down to the natural cooling setpoint temperature when natural cooling is needed and available. When natural cooling is not needed or is unavailable no natural ventilation is used. ACMs shall assume that natural cooling is needed when the building is in “cooling mode” and when the outside temperature is below the estimated zone temperature and the estimated zone temperature is above the natural cooling setpoint temperature. Only the amount of ventilation required to reduce the zone temperature down to the natural ventilation setpoint temperature is used and the natural ventilation setpoint temperature shall be constrained by the ACM to be greater than the heating setpoint temperature.

Wind Speed and Direction

Wind speed affects the infiltration rate and the natural ventilation rate. The infiltration and ventilation rate in the reference method accounts for local site obstructions. For infiltration in the reference method this is done by using Shielding Class 4 coefficients (see 2001 ASHRAE Fundamentals, Chapter 26) to determine the stack and wind driven infiltration and ventilation. This Shielding Class determination was made on the basis of the description of the Shielding Classes given in the 2001 ASHRAE Fundamentals which reads as follows:

> Heavy shielding; obstructions around most of the perimeter, buildings or trees within 30 feet in most directions; typical suburban shielding.

The reference method, CALRES, adjusts the wind speed used in calculations through a WF of 0.25. See Equation R4-29.

4.6 Heating Systems

ACMs shall use the following inputs and algorithms to calculate heating energy use.

Equation R4-31

$$NetHLoad_{hr} = \frac{HLoad_{hr} \times HDEM_{hr}}{\eta_{seasonal,dist}}$$

where

$NetHLoad_{hr}$ = The net heating load that the heating equipment sees. This accounts for air distribution duct losses. If there are no air distribution ducts then NetHLoad = $HLoad_{hr}$.

$HLoad_{hr}$ = Space heating load for the hour from the ACM simulation, Btu.

$\eta_{seasonal, dist}$ = Seasonal distribution system efficiency for the heating season from Equation R4-55.

$HDEM_{hr}$ = Heating duct efficiency multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 (no hourly adjustment) is used unless the supply ducts are located in the attic.

4.6.1 Furnaces and Boilers

Once the net heating load is known, heating energy for gas fired equipment is calculated each hour by dividing the net heating load for that hour by the AFUE. There are no hourly adjustments for part load conditions or temperature dependencies.

Equation R4-32

$$FurnFuel_{hr} = \frac{NetHLoad_{hr}}{AFUE_{eff}}$$

where

$AFUE_{Eff}$ = Annual fuel utilization efficiency. This is a constant for the year.

$NetLoad_{hr}$ = The hourly load calculated from Equation R4-31 and using algorithms similar to those described in this chapter.

4.6.2 Heat pump and Electric Furnace

The reference ACM has a heat pump model which takes account of outdoor temperature. The model uses the following inputs.

HSPF = Rated Heating Seasonal Performance Factor

EIR47 = Defaults to 1/(0.4*HSPF)

Cap47 = Rated compressor heating capacity at 47 F. Defaults to rated cooling capacity.

If the heat pump compressor is not large enough to meet the load in the hour, the ACM assumes there is sufficient backup resistance heat. In the case of an electric furnace, the load shall be met entirely by resistance heat. For heat pumps, the ACM shall calculate the hourly heating electricity consumption in kWh using the DOE2.1E heat pump algorithm.

For equipment without an HSPF rating, the HSPF may be calculated as:

Equation R4-33 $$HSPF = (3.2 \times COP) - 2.4$$

4.6.3 Air Distribution Fans

The test method for calculating AFUE ignores electric energy used by air distribution fans and the contribution of the fan motor input to the heating output. With TDV, electric energy shall be calculated separately from gas energy. For forced-air heating systems, ACMs shall calculate fan energy at the rate of 0.005 watt-hours per Btu of heat delivered by the equipment. The vast majority of residential furnaces have the fan motor in the air stream so the heat generated by the motor contributes to heating the house. This effect may be considered in calculating the TDV energy for heating.

4.7 Air Conditioning Systems

Air conditioning systems shall be sized, installed, tested and modeled according to the provisions of this section.

4.7.1 Cooling System Energy

The reference ACM calculates the hourly cooling electricity consumption in kWh using Equation R4-34. In this equation, the energy for the air handler fan and the electric compressor or parasitic power for the outdoor unit of a gas absorption air conditioner are combined. The ACM calculates the hourly cooling gas consumption in therms using Equation 4-35.

Equation R4-34 $$AC_{kWh} = \frac{Fan_{Wh} + Comp_{Wh} + PPC_{Wh}}{1{,}000}$$

Equation 4-35 $$AC_{therms} = \frac{Absorption_{Btu}}{100{,}000}$$

where

AC_{kWh}= Air conditioner kWh of electricity consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

Fan_{Wh}= Fan watt-hours for a particular hour of the simulation. See Equation R4-48.

$Comp_{Wh}$= Compressor watt-hours for a particular hour of the simulation. This is calculated using Equation R4-36.

$PPC_{Wh=}$ Parasitic Power watt-hours for gas absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R4- 44.

AC_{therms}= Air conditioner therms of gas consumption for a particular hour of the simulation. This value is calculated for each hour, combined with the TDV multipliers, and summed for the year.

$Absorption_{Btu=}$ Gas consumption in Btu for absorption air conditioners for a particular hour of the simulation. This is calculated using Equation R4-43.

Electric Compressor Systems

The reference method calculates the energy for electrically driven compressors using the algorithms described in this section.

Compressor watt-hours for a particular hour of the simulation shall be calculated using Equation R4-36.

Equation R4-36
$$Comp_{wh} = \frac{CLoad_{hr} \times CDEM_{hr}}{?_{seasonal,dist} \times CE_t} + \frac{Fan_{wh} x3.413}{CE_t}$$

where

$CLoad_{hr}$ = Space sensible cooling load for the hour from the ACM simulation (Btu).

$CDEM_{hr}$ = Cooling Duct Efficiency Multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 is used unless the supply ducts are located in the attic.

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54

$$?_{dist,seasonal} = 0.98\ DE_{seasonal} \times F_{recov}\ .$$

CE_t = Sensible energy efficiency at a particular outdoor dry bulb temperature. This is calculated using Equation R4-37 below.

Fan_{wh} = Fan watts this hour. This is calculated using Equation R4-48.

Equation R4-37
$$CE_t = EER_t \times (0.88 + 0.00156 \times (DB_t - 95))$$

where

DB_t = Outdoor dry bulb temperature taken from the CEC weather file.

EER_t = Energy efficiency ratio at a particular dry bulb temperature. EER_t is calculated using Equation R4-38 below.

Equation R4-38

When

$DB_t < 82$ ºF $EER_t = SEER_{nf}$

$82 \le DB_t < 95$ $EER_t = SEER_{nf} + ((DB_t - 82)*(EER_{nf} – SEER_{nf}) / 13)$

$DB_t \ge 95$ $EER_t = EER_{nf} - (DB_t - 95) * 0.12$

where

$SEER_{nf}$ = Seasonal energy efficiency ratio without distribution fan consumption (“nf” = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R4-39.

EER_{nf} = Energy efficiency ratio at ARI conditions without distribution fan consumption (“nf” = no fans), but adjusted for refrigerant charge and airflow. This is calculated using Equation R4-40.

Equation R4-39
$$SEER_{nf} = (1.0452 \times SEER + 0.0115 \times SEER^2 + 0.000251 \times SEER^3) \times F_{txv} \times F_{air} \times F_{size}$$

Equation R4-40 $$EER_{nf} = \left(1.0452 \times EER + 0.0115 \times EER^2 + 0.000251 \times EER^3\right) \times F_{txv} \times F_{air} \times F_{size}$$

where

SEER = Seasonal energy efficiency ratio for the air conditioner. The EER shall be used in lieu of the SEER for equipment not required to be tested for a SEER rating.

EER = Energy efficiency ratio at ARI test conditions, if not input, then values are taken from Equation R4-41.

F_{txv} = The refrigerant charge factor, default = 0.9. For systems with a verified TXV (ACM RI-2005) or verified refrigerant charge (ACM RD-2005), the factor shall be 0.96.

F_{air} = The system airflow factor, default = .925. For systems with airflow verified according to 4.7.4, F_{air} shall be 1.00.

F_{size} = Compressor sizing factor, default = 0.95. For systems sized according to the Maximum Cooling Capacity for ACM Credit (see Section 4.7.2), the factor shall be 1.0.

Equation R4-41

When

SEER <11.5 EER = 10 - (11.5 - SEER) x 0.83

SEER >= 11.5 EER = 10

Gas Absorption Systems

To determine the electric and gas energy use of gas absorption air conditioning systems the algorithms described in this section should be used.

Equation R4-42 $$Absorption_{Btu} = \frac{CLoad_{hr} \times CDEM_{hr}}{?_{seasonal,dist} \times AE_t} + \frac{Fan_{wh} \times 3.413}{AE_t}$$

Equation R4-43 $$PPC_{wh} = \frac{CLoad_{hr} \times CDEM_{hr}}{?_{seasonal,dist} \times PE_t}$$

where:

$CLoad_{hr}$ = Space sensible cooling load for the hour from the ACM simulation (Btu).

$CDEM_{hr}$ = Cooling Duct Efficiency Multiplier for the hour calculated from Equation R4-65. This value varies with each hour depending on outdoor temperature. A value of 1.00 is used unless the supply ducts are located in the attic.

$\eta_{seasonal, dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54.

AE_t = Sensible energy efficiency of the gas absorption system at a particular outdoor dry bulb temperature. This is calculated Equation R4-44 using below.

PE_t = Sensible energy efficiency of the parasitic power at a particular outdoor dry bulb temperature. This is calculated using Equation R4-45 below.

Fan_{wh} = Fan watts this hour. This is calculated using Equation R4-48.

Equation R4-44 $$AE_t = COP_t \times (0.88 + 0.00156 \times (DB_t - 95))$$

Equation R4-45 $$PE_t = PEER_t \times (0.88 + 0.00156 \times (DB_t - 95))$$

where

DB_t = Outdoor dry bulb temperature taken from the CEC weather file.

COP_t = COP (coefficient of performance for the gas consumption) of the gas absorption system at a particular dry bulb temperature calculated using Equation R4-46.

$PEER_t$ = PEER (parasitic electricity energy efficiency for the gas absorption system) at a particular outdoor dry bulb temperature calculated using Equation R4-48.

Equation R4-46

DB_t < 83 ºF	COP_t = COP82
83 < DB_t < 95	COP_t = COP82 + ((DB_t - 82)*(COP95 - COP82) / 13)
DB_t > 94	COP_t = COP95 - (DB_t - 95) * 0.00586

Equation R4-47

DB_t < 83 ºF	$PEER_t$ = PEER82
83 < DB_t < 95	$PEER_t$ = PEER82 + ((DB_t - 82)*(PEER95 - PEER82) / 13)
DB_t > 94	$PEER_t$ = PEER95 - (DB_t - 95) * 0.00689

where

CAP95= Rated capacity of the gas absorption system, Btuh, input by the compliance user

COP95 = Rated COP of the gas absorption system, input by compliance user

PPC = Parasitic electric energy at rated conditions, W, input by compliance user

COP82 = COP95 * 1.056

PEER95= CAP95 / PPC, Btu / Wh

PEER82= PEER95 * 1.056

Fan Energy for Cooling

While in a cooling mode, the fan energy associated with the air conditioner is calculated separately from the compressor energy according to Equation R4-48. Calculations are performed hourly.

Equation R4-48
$$Fan_{wh} = \frac{FanW/Btu \times CLoad_{hr} \times CDEM_{hr}}{\eta_{seasonal,dist}}$$

where

FanW/Btu = Fan watts per Btu of rated cooling capacity. This defaults to 0.015 W/Btu. The default value shall be used for the Standard design. Alternate FanW/Btu may be used in ACM calculations for the Proposed design if the actual installed fan watts are less than or equal to the simulation value based on measurements certified by the installer and verified by a rater using the procedure in ACM Appendix RE-2005.

$\eta_{seasonal,\ dist}$ = Seasonal distribution system efficiency for the cooling season from Equation R4-54.

4.7.2 Compressor Sizing

The Design Cooling Capacity shall be calculated using the procedure in ACM RF-2005. The Maximum Cooling Capacity for ACM Credit shall be calculated using the procedure in ACM RF-2005. For ACM energy calculations all loads are assumed to be met in the hour they occur regardless of the compressor size.

Correctly sized systems installed so they operate at full capacity are desirable because oversized cooling systems have been shown to result in larger peak electrical demands. Systems which have the combination of verified adequate airflow, sealed and tested new duct systems, and proper charge (or alternatively a TXV) and also meet the requirements for Maximum Cooling Capacity for ACM Credit may take credit in ACM calculations by setting the Fsize factor (see Equation R4-39 and Equation R4-40) to 0.95. For all other systems the Fsize factor shall be set to 1.0.

4.7.3 Cooling System Refrigerant Charge

Proper refrigerant charge is necessary for electrically driven compressor air conditioning systems to operate at full capacity and efficiency. The presence of a thermostatic expansion valve (TXV) mitigates the impact of charge problems. Field measurements indicate that typical California air conditioning systems are installed without proper charge, and for ACM energy calculations, the F_{txv} factor is set to 0.90 to account for the impact of this condition. If the system without a TXV is properly charged or a TXV is installed, certified and verified according to the procedures of ACM RD-2005 the F_{txv} factor may be set to 0.96 for ACM energy calculations. See Equation R4-39 and Equation R4-40. Credit for refrigerant charge is not available for package systems.

4.7.4 Air Handler Airflow

The efficiency of an air conditioning system is affected by airflow across the evaporator coil. Cooling system airflow is specified in cubic feet per minute per ton (cfm/ton) where one ton of capacity is 12,000 Btu/hour at ARI rated conditions. Cooling airflow is the flow achieved under normal air conditioning operation with the cooling coil wet from condensation.

Adequate Airflow Verification

Verifying adequate airflow is required to allow air conditioning systems to operate at their full efficiency and capacity. Credit may be taken for adequate airflow in ACM calculations by setting the F_{air} factor (see Equation R4-39 and Equation R4-40) to 1.0, but airflow shall be tested, certified and verified using the procedures of ACM RE-2005. When an adequate airflow credit is claimed, the duct design, layout, and calculations shall also be submitted to the local enforcement agency and to a certified HERS rater. Without airflow tests, no credit is allowed for ACM energy calculations and the F_{air} multiplier shall be set to 0.925.

The installer shall measure and certify the airflow. The certified HERS rater shall verify the existence of the duct design layout and calculations, verify that the field installation is consistent with this design, and diagnostically test and verify the airflow rate.

Sufficient Flow for Valid Standard Refrigerant Charge Test

Sufficient airflow is also required to ensure that the refrigerant charge procedure in ACM RD-2005 will produce valid results. Verifying sufficient airflow is a prerequisite for the refrigerant charge test. Either the flow measurement procedure or the temperature split test of ACM RD-2005 may be used to demonstrate Sufficient Airflow.

Air Handler Fan Flow

Table R4-9 shows the criteria used for calculations and measurement of airflow for cooling systems. If a flow test is done using the fan only switch on the air handler, the coil will be dry allowing higher airflow, and the Dry Coil criterion shall be used.

Table R4-9 – Airflow Criteria

Note: All airflows are for the fan set at the speed used for air conditioning.

Test and Condition	Cooling airflow (Wet Coil)	Test Flow if Dry Coil
Default Cooling Airflow	300 cfm/ton	N/A
Flow needed for a valid refrigerant charge test	350 cfm/ton (See Note 1)	400 cfm/ton
Adequate Airflow	400 cfm/ton	450 cfm/ton
Note 1. In lieu of airflow measurements, the system can pass the temperature split test documented in ACM RD-2005.		

4.8 Duct Efficiency

The procedures in this section shall be used to calculate the efficiency of duct systems. For the purposes of duct efficiency calculations, the supply duct begins at the exit from the furnace or air handler cabinet.

4.8.1 Building Information and Defaults

The ACM shall use values for the parameters in Table R4-10 to calculate duct efficiencies. Standard design values and proposed design defaults are also shown. Proposed designs may claim credit for other values using the procedures in the following sections.

Table R4-10 – Duct Efficiency Input Parameters and Defaults

Parameter		Standard Design Value	Proposed Design Default
1.	Duct Location	Ducts in the attic	Ducts in the attic
2.	Insulation level of ducts	Package D requirement	Mandatory Minimum Requirement
3.	The surface area of ducts	27% of conditioned floor area (CFA) for supply duct surface area; 5% CFA for return duct surface area in single story dwellings and 10% CFA for return duct surface area in dwellings with two or more stories.	
4.	The leakage level	Sealed and tested.	Untested
5.	Fan flow	Default Cooling Airflow (Table R4-9)	
6.	Attic radiant barrier.	Yes in climate zones where required by Package D, otherwise No	No radiant barrier

When more than one HVAC system serves the building or dwelling, the HVAC distribution efficiency is determined for each system and a conditioned floor area-weighted average seasonal efficiency is determined based on the inputs for each of the systems.

See Section 3.8 for information on existing HVAC systems that are extended to serve an addition.

Diagnostic inputs may be used for the calculation of improved duct efficiency in the *Proposed Design*. The diagnostics include observation of various duct characteristics and measurement of duct leakage as described in the following sections. These observations and measurements replace those assumed as default values.

4.8.2 Duct Location

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Note that the area of supply ducts located in conditioned space shall be ignored in calculating conduction losses but supply duct leakage is not affected by supply duct location.

Return Duct Location

If return ducts are located entirely in the basement, the calculation shall assume basement conditions for the return duct efficiency calculation. Otherwise, the return duct shall be entirely located in the attic for the purposes of conduction and leakage calculations. Return duct surface area is not a compliance variable.

Default Supply Duct Location

Default supply duct locations shall be as shown in Table R4-11. The supply duct surface area for crawl space and basement applies only to buildings or zones with all supply ducts installed in the crawl space or basement. If the supply duct is installed in locations other than crawl space or basement, the default supply duct location shall be "Other." For houses with 2 or more stories 35% of the default duct area may be assumed to be in conditioned space as shown in Table R4-11. The surface area of supply ducts located in conditioned space shall be ignored in calculating conduction losses. The *Standard Design* building is assumed to have the same number of stories as the *Proposed Design* for purposes of determining the duct efficiency.

Table R4-11 – Location of Default Supply Duct Area

Supply duct location	**Location of Default Supply Duct Surface Area**	
	One story	Two or more story
All in Crawl Space	100% crawl space	65% crawl space 35% conditioned space
All in Basement	100% Basement	65% basement 35% conditioned space
Other	100% attic	65% attic 35% conditioned space

DiagnosticSupply Duct Location

Supply duct location and areas other than the defaults shown in Table R4-11may be used following the procedures of 4.8.5.

4.8.3 Duct Surface Area

The supply-side and return-side duct surface areas shall be treated separately in distribution efficiency calculations. The duct surface area shall be determined using the following methods.

Return Duct Surface Area

Return duct surface area is not a compliance variable and shall be calculated using Equation R4-49.

Equation R4-49 $$A_{r,out} = K_r \times A_{floor}$$

Where K_r (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.

Default Supply Duct Surface Area

The standard design and default supply duct surface area shall be calculated using Equation R4-50.

Equation R4-50 $$A_{S,\,out} = 0.27 \times A_{floor} \times K_S$$

Where Ks (supply duct surface area coefficient) shall be 1 for one story building and 0.65 for two or more stories.

Supply Duct Surface Area for Less Than 12 feet of Duct Outside Conditioned Space

For proposed design HVAC systems with air handlers located outside the conditioned space but with less than 12 lineal feet of duct located outside the conditioned space including air handler and plenum, the supply duct surface area outside the conditioned space shall be calculated using Equation R4-51.

Equation R4-51 $$A_{s,out} = 0.027 \times A_{floor}$$

Diagnostic Duct Surface Area

Proposed designs may claim credit for reduced surface area using the procedures in 4.8.5.

4.8.4 Duct System Insulation

General

An air film resistance of 0.7 (h-ft²-°F/Btu) shall be added by the ACM to the insulation R-value to account for external and internal film resistance. For the purposes of conduction calculations in both the Standard and Proposed designs, 85% of the supply and return duct surface shall be assumed to be duct material at it's specified R-value and 15% shall be assumed to be air handler, plenum, connectors and other components at the mandatory minimum R-value.

Standard Design Duct Insulation R-value

Package D required duct insulation R-values shall be used in the Standard design.

Proposed Design Duct Insulation R-value

The default duct wall thermal resistance shall be the mandatory requirement. Higher insulation levels may be used in the proposed design if all the ducts outside conditioned space are insulated to this value or greater. Credit for systems with mixed insulation levels or ducts buried in the attic require the diagnostic procedure in 4.8.5.

4.8.5 Diagnostic Supply Duct Location, Surface Area and R-factor

Credit is available for supply duct systems entirely in conditioned space, with reduced surface area in unconditioned spaces and combinations of higher performance insulation. In order to claim this credit the detailed duct system design shall be documented on the plans, and the installation shall be certified by the installer and verified by a HERS rater. The size, R-value, and location of each duct segment in an unconditioned space and if buried in attic insulation, the information described below shall be shown in the design and entered into the ACM. The ACM shall calculate the area and effective R-value of the duct system in each location using the procedures specified below.

Surface Area and Location

The surface area of each supply duct system segment shall be calculated based on its inside dimensions and length. The total supply surface area in each unconditioned space location (attic, attic with radiant barrier, crawl space, basement, other) shall be the sum of the area of all duct segments in that location. The ACM shall assign duct segments located in "other" locations to the attic location for purposes of calculation. The surface area of supply ducts completely inside conditioned space need not be input in an ACM and is not included in the calculation of duct system efficiency. The area of ducts in floor cavities or vertical chases that are surrounded by conditioned space and separated from unconditioned space with draft stops are also not included.

Effective R-value

The effective R-value of a supply or return duct system constructed entirely of materials of one rated R-value shall be the rated R-value plus the film coefficient. If materials of more than one R-value are used, the area weighted effective R-value shall be calculated by the ACM using Equation R4-52 and including each segment of the duct system which has a different R-value.

Equation R4-52

$$R_{eff} = \frac{(A_1 + A_2 .... + A_N)}{\left[\frac{A_1}{R_1} + \frac{A_2}{R_2} .... + \frac{A_N}{R_N}\right]}$$

where

R_{eff} = Area weighted effective R-value of duct system for use in calculating duct efficiency,(h-ft²-°F/Btu)

A_N = Area of duct segment n, square feet.

R_n = R-value of duct segment n including film resistance, (duct insulation rated R + 0.7), (h-ft²-°F/Btu)

Buried Attic Ducts

Ducts partly or completely buried in blown attic insulation in dwelling units meeting the requirements for High Insulation Quality (ACM RH) and Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems (ACM RC) may take credit for increased effective duct insulation using the following procedure. The duct design shall identify the segments of the duct that meet the requirements for being buried, and these shall be separately input into the ACM. Ducts to be buried shall have a minimum of R-4.2 duct insulation prior to being buried. The ACM shall calculate the correct R-value based on the specified attic insulation R-value, insulation type, and duct size for ducts installed on the ceiling, and whether the installation meets the requirements for deeply buried ducts for duct segments buried in lowered areas of ceiling. Correct installation of the duct system and attic insulation shall be certified by the installer and verified by a certified HERS rater (including that the requirements of ACM RH and ACM RC are met).

Buried Ducts on the Ceiling

The portions of duct runs directly on or within 3.5 inches of the ceiling gypsum board and surrounded with blown attic insulation of R-30 or greater may take credit for increased effective duct insulation as shown in Table R4-12. Credit shall be allowed for buried ducts on the ceiling only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above.

Deeply Buried Ducts

Duct segments deeply buried in lowered areas of ceiling and covered by at least 3.5" of insulation above the top of the duct insulation jacket may claim effective insulation of R-25 for fiberglass insulation and R-31 for cellulose insulation.

Table R4-12 – Buried Duct Effective R-values

	Nominal Round Duct Diameter								
Attic Insulation	4"	5"	6"	7"	8"	10"	12"	14"	16"
	Effective Duct Insulation R-value for Blown Fiberglass Insulation								
R-30	R-13	R-13	R-13	R-9	R-9	R-4.2	R-4.2	R-4.2	R-4.2
R-38	R-25	R-25	R-25	R-13	R-13	R-9	R-9	R-4.2	R-4.2
R-40	R-25	R-25	R-25	R-25	R-13	R-13	R-9	R-9	R-4.2
R-43	R-25	R-25	R-25	R-25	R-25	R-13	R-9	R-9	R-4.2
R-49	R-25	R-25	R-25	R-25	R-25	R-25	R-13	R-13	R-9
R-60	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-25	R-13
	Effective Duct Insulation R-value for Blown Cellulose Insulation								
R-30	R-9	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
R-38	R-15	R-15	R-9	R-9	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
R-40	R-15	R-15	R-15	R-9	R-9	R-4.2	R-4.2	R-4.2	R-4.2
R-43	R-15	R-15	R-15	R-15	R-9	R-4.2	R-4.2	R-4.2	R-4.2
R-49	R-31	R-31	R-15	R-15	R-15	R-9	R-9	R-4.2	R-4.2
R-60	R-31	R-31	R-31	R-31	R-31	R-15	R-15	R-9	R-9

4.8.6 Fan Flow

Default System Fan Flow

The default fan flow for an air conditioner and for heating with a heat pump in all climate zones shall be obtained from Table R4-9.

The default heating fan flow for forced air furnaces for all climate zones shall be calculated as follows:

Equation R4-53 $Q_e = 0.50 \times A_{floor}$

4.8.7 Duct Leakage

Duct leakage factors shown in Table R4-13 shall be used in calculations of delivery effectiveness. Table R4-13 shows default duct leakage factors for dwelling units. Sealed and tested duct systems require the diagnostic leakage test by the installer and verification by a HERS rater meeting the criteria described in ACM RC-2005. The duct leakage factors for sealed and tested new duct systems correspond to sealed duct requirements in newly constructed dwelling units, to entirely new duct systems in existing dwelling units, and to duct systems in alterations and additions that have been sealed to meet the duct leakage requirements of newly constructed buildings. The duct leakage factors for sealed and tested duct systems in existing dwelling units apply only to sealed duct requirements for alterations to existing dwelling units and to extensions of existing duct systems to serve additions. See Section 3.8 for ducts in existing dwelling units that are sealed and tested in conjunction with alterations or additions.

Table R4-13 – Duct Leakage Factors

Case	$a_s = a_r =$
Untested duct systems in homes built prior to June 1, 2001	0.86
Untested duct systems in homes built after June 1, 2001	0.89
Sealed and tested duct systems in existing dwelling units	0.915
Sealed and tested new duct systems	0.96

4.8.8 Seasonal Distribution System Efficiency

ACMs shall use the following algorithms to calculate duct and HVAC distribution efficiency.

The seasonal distribution system efficiency shall be calculated separately for the heating and cooling seasons using Equation R4-54 based on the seasonal delivery effectiveness from Equation R4-55 and the recovery factor from Equation R4-64. Note that $DE_{seasonal}$, F_{recov} shall be calculated separately for cooling and heating seasons. Distribution system efficiency shall be determined using the following equation:

Equation R4-54
$$?_{dist,seasonal} = 0.98\, DE_{seasonal} \times F_{recov}$$

where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass. F_{recov} is calculated in Equation R4-64.

4.8.9 Seasonal Delivery Effectiveness

The seasonal delivery effectiveness for heating or cooling systems shall be calculated using Equation R4-55. This value shall be calculated separately for the heating season and the cooling season.

Equation R4-55
$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_r a_r) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}$$

where

B_s = Conduction fraction for supply as calculated in Equation R4-56.

B_r = Conduction fraction for return as calculated in Equation R4-57.

ΔT_e = Temperature rise across heat exchanger, ºF. This value changes for heating and cooling modes.

ΔT_r = Temperature difference between indoors and the ambient for the return, ºF. This value changes for heating and cooling modes.

ΔT_s = Temperature difference between indoors and the ambient for the supply, ºF. This value changes for heating and cooling modes.

a_r = Duct leakage factor (1-return leakage) for return ducts. A value is selected from Table R4-13

a_s = Duct leakage factor (1-supply leakage)p for supply ducts. A value is selected from Table R4-13

Equation R4-56
$$B_s = \exp\left(\frac{-A_{s,out}}{1.08 Q_e \times R_s}\right)$$

Equation R4-57
$$B_r = \exp\left(\frac{-A_{r,out}}{1.08Q_e \times R_r}\right)$$

where

$A_{s,out}$ = Surface area of supply duct outside conditioned space, ft². See Sections 4.8.1, 4.8.2 and 4.8.3.

$A_{r,out}$ = Surface area of return duct outside conditioned space, ft^2. See Sections 4.8.1, 4.8.2 and 4.8.3.

Q_e = Flow through air handler fan at operating conditions, cfm. This is determined from Section 4.7.4.

R_r = The effective thermal resistance of return duct, h ft^2 F/Btu. See Section 4.8.4 and 4.8.5.

R_s = The effective thermal resistance of supply duct, h ft^2 F/Btu. See Section 4.8.4 and 4.8.5.

4.8.10 Climate and Duct Ambient Conditions for Ducts Outside Conditioned Space

Duct ambient temperature for both heating and cooling for different duct locations shall be obtained from Table R4-14. Attic temperatures for houses with radiant barriers also shall be obtained from Table R4-14. Reduction of attic temperature and the reduction in solar radiation effect due to radiant barriers shall only be applied to cooling calculations. The eligibility criteria for radiant barriers is given in Section 4.2.1. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F.

Table R4-14 – Assumptions for Duct Ambient Temperature (ºF)

	Ambient Temperature for Heating, $T_{heat,amb}$			Ambient Temperature for Cooling, $T_{cool,amb}$				
Climate zone	Attic	Crawl Space	Basement	Attic	Attic w/ radiant barrier (supply)	Attic w/ radiant barrier (return)	Crawl Space	Basement
1	52.0	52.2	48.9	60.0	65.4	61.2	54.0	49.1
2	48.0	48.7	56.5	87.0	84.3	84.2	78.0	64.5
3	55.0	54.9	58.3	80.0	79.4	78.2	71.8	62.8
4	53.0	53.1	56.6	79.0	78.7	77.4	70.9	61.4
5	49.0	49.6	52.3	74.0	75.2	73.1	66.4	56.8
6	57.0	56.7	59.9	81.0	80.1	79.1	72.7	64.1
7	62.0	61.1	60.4	74.0	75.2	73.1	66.4	61.6
8	58.0	57.6	60.1	80.0	79.4	78.2	71.8	63.9
9	53.0	53.1	59.6	87.0	84.3	84.2	78.0	66.4
10	53.0	53.1	61.1	91.0	87.1	87.6	81.6	68.9
11	48.0	48.7	59.5	95.0	89.9	91.0	85.1	69.5
12	50.0	50.4	59.3	91.0	87.1	87.6	81.6	67.8
13	48.0	48.7	58.4	92.0	87.8	88.4	82.4	67.6
14	39.0	40.7	55.4	99.0	92.7	94.4	88.7	68.6
15	50.0	50.4	63.4	102.	94.8	96.9	91.3	74.6
16	32.0	34.4	43.9	80.0	79.4	78.2	71.8	54.1

4.8.11 Calculation of Duct Zone Temperatures for Multiple Locations

The temperatures of the duct zones outside the conditioned space are determined in Table R4-14 for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures.

Equation R4-58

$$T_{amb,s} = \frac{(A_{s,attic} + 0.001)T_{attic} + A_{s,crawl} \times T_{crawl} + A_{s,base} \times T_{base}}{A_{s,out}}$$

Equation R4-59

$$T_{amb,r} = \frac{A_{r,attic}\ T_{attic} + A_{r,crawl} \times T_{crawl} + A_{r,base} \times T_{base}}{A_{r,out}}$$

The return ambient temperature, $T_{amb,r}$, shall be limited as follows:

- For heating, the maximum $T_{amb,r}$ is $T_{in,heat}$.
- For cooling, the minimum $T_{amb,r}$ is $T_{in,cool}$.

4.8.12 Temperature Difference Across Heat Exchanger

The temperature difference across the heat exchanger is determined by Equation R4-60:

For heating:

Equation R4-60 $\Delta T_e = 55$

And Equation R4-61 for cooling:

Equation R4-61 $\Delta T_e = -20$

4.8.13 Indoor to Duct Location Temperature Differences

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s, and return, ΔT_r , shall be calculated using the indoor and the duct ambient temperatures.

Equation R4-62 $\Delta T_s = T_{in} - T_{amb,s}$

Equation R4-63 $\Delta T_r = T_{in} - T_{amb,r}$

4.8.14 Thermal Regain (F_{regain})

The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The thermal regain factors that are required to be used are provided in Table R4-15.

Table R4-15 – Thermal Regain Factors

Supply Duct Location	Thermal Regain Factor [F_{regain}]
Attic	0.10
Crawl Space	0.12
Basement	0.30
Other	0.10

4.8.15 Recovery Factor (F_{recov})

The recovery factor, F_{recov}, shall be calculated based on the thermal regain factor, F_{regain}, and the duct losses without return leakage.

Equation R4-64
$$F_{recov} = 1 + F_{regain}\left(\frac{1 - a_s B_s + a_s B_s (1 - B_r)\dfrac{\Delta T_r}{\Delta T_e} + a_s (1 - B_s)\dfrac{\Delta T_s}{\Delta T_e}}{DE_{seasonal}}\right)$$

4.9 Hourly Attic Duct Efficiency Multipliers

The algorithm in this section shall be used to model the hourly variation in duct efficiency for ducts located in attics. No hourly variation is modeled for ducts located in spaces other than attics. The multipliers are determined as described in Section 4.9.1 below:

4.9.1 Hourly Duct Efficiency Multipliers

The hourly duct efficiency multiplier for ducts in attics shall be calculated for each hour using Equation R4-65 through Equation R4-68.

Equation R4-65
$$DEM_{hr} = 1 + C_{DT} \times \left(\frac{\Delta T_{sol,hr}}{?T_{sol,season}} - 1 \right)$$

Equation R4-66
$$\Delta T_{sol,hr} = T_{solair,hr} - T_{in,hr}$$

Equation R4-67
$$T_{solair,hr} = T_{amb,hr} + \left(\frac{a}{h_o} \right) \times I_{hor,hr} - ?T_{sky}$$

Equation R4-68
$$C_{DT} = C_0 + C_R / R_{duct} + C_L L_{duct}$$

where

DEM_{hr} =	The hourly duct efficiency multiplier for ducts located in all locations. This value is calculated for each hour and separately for the heating season ($HDEM_{hr}$) and cooling season ($CDEM_{hr}$).
$T_{solair,\,hr}$	Sol-air temperature, ºF. See Equation R4-67.
$T_{in,hr}$	Indoor air dry-bulb temperature from simulation, °F.
$T_{amb,hr}$	Outdoor air dry-bulb temperature, °F. From the CEC weather file.
ΔT_{sky}	Reduction of sol-air temperature due to sky radiation, = 6.5 ºF.
$I_{hor,hr}$	Global solar radiation on horizontal surface, Btu/h-ft². From the CEC weather file.
α	Solar absorptivity of roof = 0.50.
h_o	Outside surface convection coefficient, = 3.42 Btu/h-ft²-ºF.
$\Delta T_{sol,\,season}$	Energy weighted seasonal average difference between sol-air and indoor temperatures. This is taken from Table R4-17.
R_{duct}	Duct insulation R-value, hr ft^{2}°F/Btu.
L_{duct}	Duct leakage as fraction of supply airflow, dimensionless. See Table R4-13.
C_{DT}, C_0, C_R, C_L	Regression coefficients. See Table R4-16.

Table R4-16 – Regression Coefficients

		Cooling		Heating	
		Radiant Barrier	No Radiant Barrier	Radiant Barrier	No Radiant Barrier
C_0	(Unitless)	0.0078	0.0186	0.0350	0.0205
C_R	(h-ft²-ºF/Btu)	0.1222	0.0877	0.0794	0.1202
C_L	(Unitless)	0.5480	0.2995	0.0714	0.2655

Table R4-17 – Seasonal Sol-Air Temperature Difference, °F

Climate Zone	Cooling	Heating
1	23.00	-20.01
2	31.69	-23.64
3	23.66	-18.90
4	26.29	-21.13
5	26.02	-20.25
6	23.79	-17.12
7	25.17	-17.16
8	30.89	-19.46
9	32.73	-18.85
10	33.34	-21.53
11	34.24	-24.38
12	34.65	-23.31
13	34.53	-22.92
14	35.29	-25.64
15	33.33	-20.32
16	29.43	-29.86

4.10 Water Heating Calculations

The water heating budget is the TDV energy that would be used by a system that meets the requirements of the standards (see Section 3.7 for details). The calculation procedure is documented in ACM RG-2005.

5. Minimum Capabilities Tests

This chapter describes the methods used to test the minimum modeling capabilities of candidate ACMs. There are separate tests for space conditioning tests and water heating tests. Most of the space conditioning tests are performed using a simple square building prototype (see Figure R5-7). The water heating tests are performed relative to two prototype water heating systems. Most of the tests are performed in only five climate zones, but some are performed in all sixteen climate zones.

5.1 Overview

Two types of tests are performed: accuracy tests and standard design generator tests (or custom budget tests). While ACMs shall pass all these tests, the Energy Commission, at its discretion, may require additional tests to justify the accuracy of the candidate ACM to confirm other required features.

5.1.1 Accuracy Tests

This section describes the general testing concept that is used for the accuracy tests. For the prototype buildings and the specified variations, candidate ACMs shall generate an estimate of TDV energy and this is compared to the TDV energy that is estimated with the reference method. The TDV energy of the candidate ACM shall be within an acceptable tolerance of the reference method in order for the ACM to pass the test. The margin of acceptability is defined below and may change for each group of tests. For the space conditioning tests, only the TDV energy for space conditioning is considered and for the water heating tests only the TDV energy for water heating is considered.

General Procedure

Basecase. Each test begins with a prototype building or system that exactly complies with the prescriptive criteria (package D); this is the basecase building or system. The basecase has a zero compliance margin, e.g. it exactly complies with the standard. In another parlance, it is the custom budget building.

Discrete Modifications. A set of discrete modifications are then made to the basecase building or system, e.g. the ducts are sealed, walls and ceilings are field verified for good construction quality or a different type of heating or cooling equipment is installed. The discrete modifications are defined for each test and may vary slightly for each climate zone identified for the test. The discrete modifications are selected to represent important compliance measures. The discrete modifications will either improve or degrade the TDV energy performance of the basecase building, e.g. the compliance margin of the modified basecase will become either positive or negative.

Continuous Variable. A continuous variable, which is identified for each test, is then increased or reduced so that the modified basecase complies by a specified tolerance and fails by a specified tolerance. The continuous variables have a predictable and continuous impact on the TDV energy of the proposed design. Examples are SEER, AFUE, and glass area (above 20% of the floor area). The value for the continuous variable that causes the modified basecase to pass by the specified tolerance is the “passing solution” and the value that causes failure by the specified tolerance is the “failing solution”. The “failing solution” shall result in TDV energy as close as possible to the negative tolerance, but shall be greater than the negative tolerance. The “passing solution” shall result in TDV energy as close as possible to the positive tolerance but shall be less than the positive tolerance. The positive and negative tolerances are defined for each test, but in general they are 1.0 kTDV/ft²-y or 3% of the baseline TDV energy whichever is greater.

The procedure is illustrated in Figure R5-1 through Figure R5-4. In these diagrams, the base case building is represented by point “A”. The vertical axis represents the compliance margin with a positive compliance margin (building or system passes) above the horizontal axis and a negative compliance margin (building or system fails) below the horizontal axis. Figure R5-1 and Figure R5-3show instances when the discrete modifications produce a positive compliance margin and Figure R5-2 and Figure R5-4 are examples of discrete modifications that produce a negative compliance margin. When the discrete modifications produce a change in TDV energy that is within the specified tolerances, the passing solution or failing solutions are equal to the basecase value of the continuous variable. This situation is illustrated in Figure R5-3 and Figure R5-4.

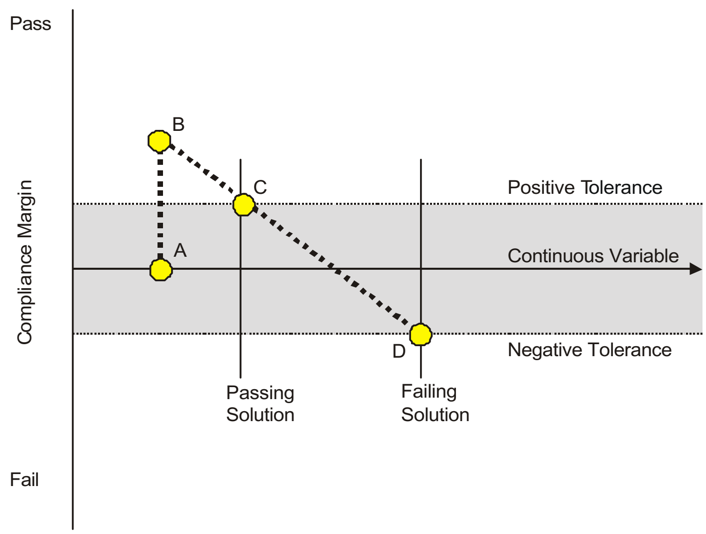

Figure R5-1 – Testing Concept – Discrete Modifications Produce Positive Compliance Margin
The discrete modifications produce a positive compliance margin that exceeds positive tolerance. Both the passing solution and the failing solutions for the continuous variable are determined.

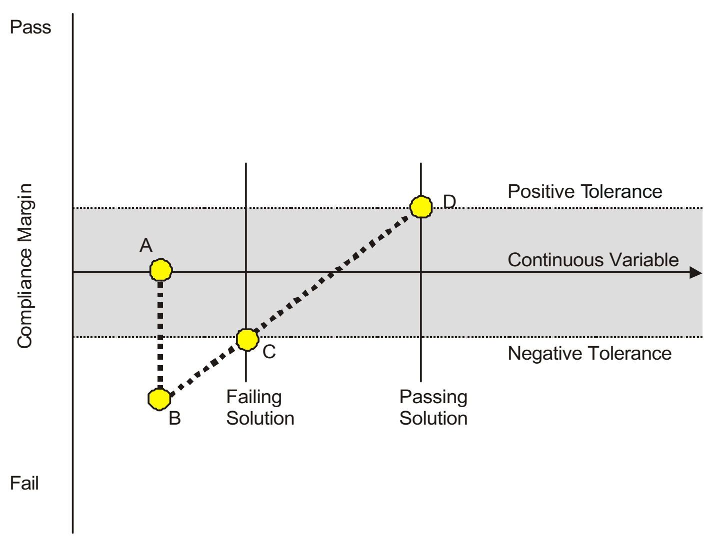

Figure R5-2 – Testing Concept – Discrete Modifications Produce Negative Compliance Margin
The discrete modifications produce a negative compliance margin that exceeds negative tolerance. Both the passing solution and the failing solutions for the continuous variable are determined.

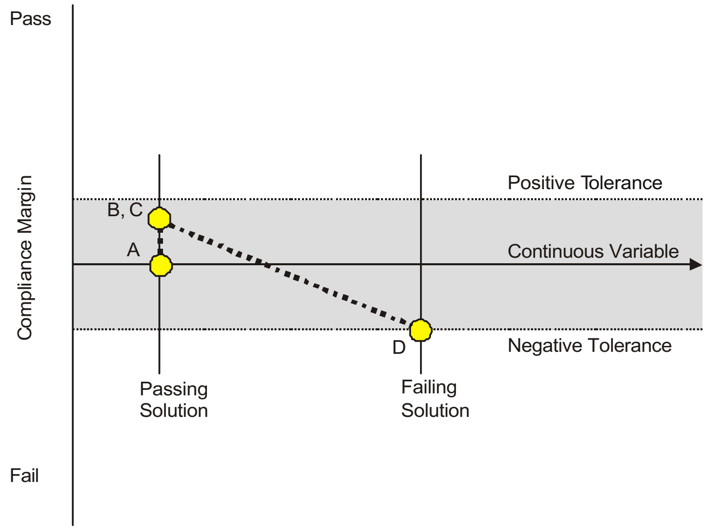

Figure R5-3 – Testing Concept – Discrete Modifications Produce Positive But Small Compliance Margin
The discrete modifications produce a positive compliance margin that is less than the positive tolerance. The passing solution for the continuous variable is equal to the basecase; the failing solution is determined by the vendor..

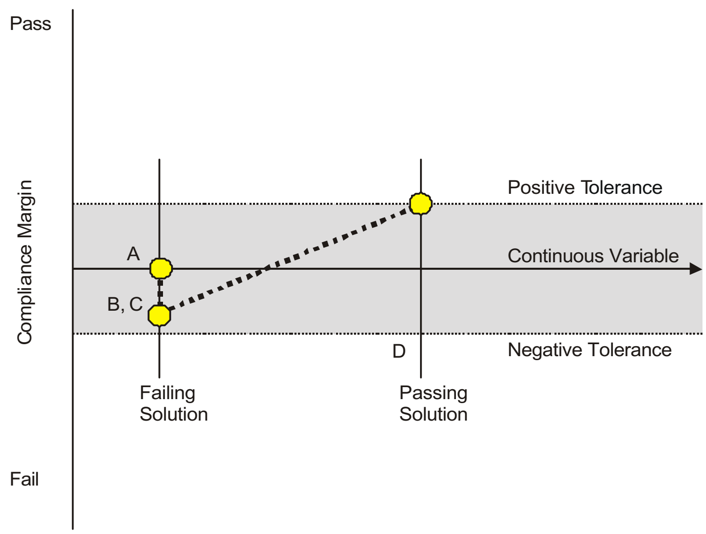

Figure R5-4 – Testing Concept – Discrete Modifications Produce Negative But Small Compliance Margin
The discrete modifications produce a negative compliance margin that is within the negative. The failing solution for the continuous variable is equal to the basecase; the passing solution is determined by the vendor.

Acceptance Criteria

For every test, the Energy Commission reference method shall pass the modified basecase when data for the passing solution is entered and fail the modified basecase when data for the failing solution is entered. The acceptance criteria shall be satisfied for all tests. In addition to producing estimates that are within the tolerances, the tests are also used to verify that the standard reports are correctly produced, as required in Chapter 2. For instance, many of the discrete modifications trigger measures that shall be listed in the “Special

Features and Modeling Assumptions" section of the Certificate of Compliance. Finally, the tests will be used to verify that the standard design building is correctly defined, as specified in Chapter 3.

5.1.2 Standard Design Tests

The acceptance criteria for the standard design generator tests use a different approach from the accuracy tests. Two types of tests are used to verify that the standard design is created according to the rules specified in Chapter 3: These are defined below along with the acceptance criteria for each.

Standard Design Equivalent Tests

The standard design equivalent tests consist of matched pairs of computer runs: a proposed design and its standard design equivalent. The standard design equivalent is the proposed design reconfigured according to the standard design rules in Chapter 3 to be in exact compliance with the prescriptive requirements (package D). The ACM vendor is required to create the proposed design and standard design equivalent input files and submit them with the application for approval.

Two Certificates of Compliance are produced: one for the proposed design and one for the standard design equivalent. The standard design TDV energy budget on the proposed design Certificate of Compliance shall be equal to the TDV energy use shown in both the standard design energy budget and proposed design columns of the standard design equivalent computer run. See Figure R5-5.

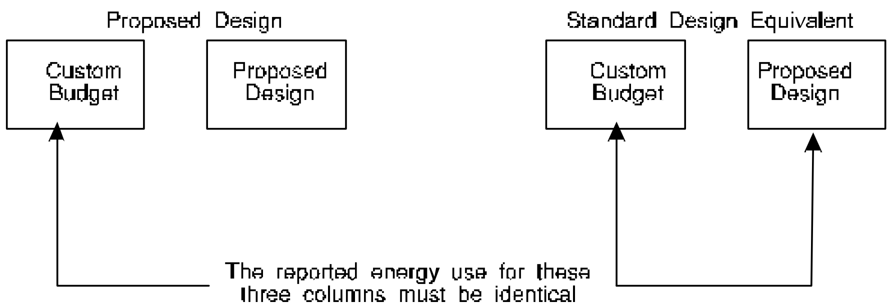

Figure R5-5 – Custom Budget Tests

Neutral Variable Tests.

The second series of standard design equivalent tests are the neutral variable tests. Neutral variables are building features that are unchanged between the standard design and the proposed design. An example of a neutral variable is glass area, below the prescriptive limit of 20%. In this series of tests, a change is specified in one of the neutral variables and the compliance margin has to remain within a certain tolerance.

5.1.3 Labeling Tests and Computer Simulations

Each of the tests has a specific label that includes the test series, the number of the test, the prototype used in the test and the climate zone for which the test is performed. Using a precise designation to make it easier to keep track of the many computer simulations will ease the Energy Commission review process. The following labeling scheme described in Figure R5-6 shall be used:

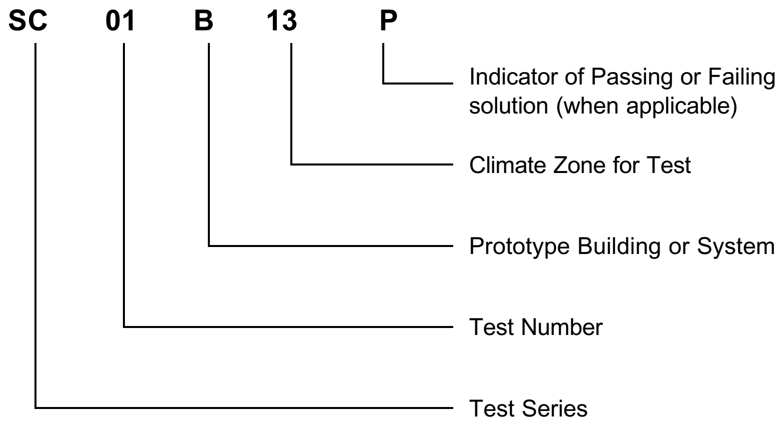

Figure R5-6 – Labeling of Computer Simulations

ACM input and output files shall use the same labeling scheme, but with a “P” or “F” concatenated on the end to indicate if the file represents the passing or failing solution.

5.1.4 Documentation

The ACM vendor shall record the results of the tests on the forms provided in Appendix RA-2005 and provide electronic copies of the input files to the Energy Commission. The filenames shall include the test label (see below) with a “P” or “F” concatenated to the file name to indicate if the file represents the passing solution or the failing solution. The form (Appendix RA-2005) includes an entry for the TDV energy for the passing solution and the failing solution. The forms also include the continuous variable values for the passing and failing solutions as well as the ACM filenames for the passing and failing cases.

5.2 Space Conditioning Tests

This section describes the space conditioning tests that shall be performed by the ACM vendor. Three groups of tests are described. The first verify that space conditioning TDV energy is predicted with an acceptable tolerance of that predicted by the reference method. The second series of tests verify that the custom budget or standard design is correctly defined. The third series of tests verify that the ACM calculates TDV energy correctly for additions and alterations to low-rise residential buildings.

5.2.1 Accuracy Tests (SC)

The accuracy tests verify that the candidate ACM passes and fails buildings in a manner consistent with the reference method.

Prototype Buildings

The space conditioning accuracy tests are performed with two prototype buildings. The geometry of the prototype buildings and other features are described below and illustrated in Figure R5-7. The attic is not shown in Figure R5-7 since the ACM modeling rules do not require the attic to be explicitly modeled as a separate thermal zone.

Both prototype A and B are a square box measuring 40 ft by 40 ft and 10 ft tall. A single 80 ft² window on each façade (total window area is 20% of the floor area). The facades face exactly north, east, south and west. The thermal performance of all building envelope elements is in exact compliance with the prescriptive requirements (package D in the standards). The prototypes have a gas furnace and a split system air conditioner with air distribution ducts located in an attic.

A Prototype A has a slab-on-grade.

B Prototype B has raised floor construction.

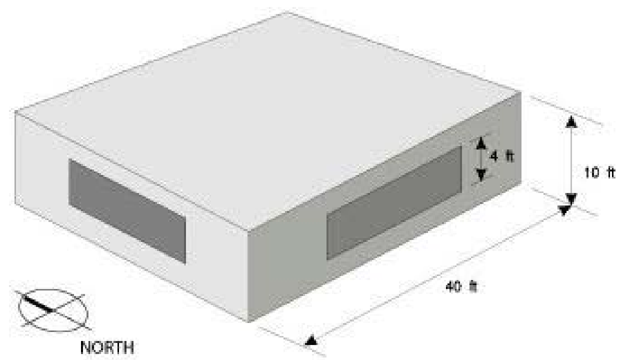

Figure R5-7 – Prototype Buildings A and B

Test Descriptions

Table R5-1 describes each of the space conditioning tests that shall be performed. The space conditioning accuracy tests use the series designation “SC.”

Table R5-1 – Summary of the Space Conditioning Tests

Series	*Number*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
SC	0	A, B	All	None	None
SC	1	A	3, 9, 12, 14, 16	**SEER**. Increase the cooling equipment efficiency (SEER) from the basecase condition of 12.0 to 14.0.. Use the default EER for both the SEER 12.0 and SEER 14.0 cases. Make no changes to the air distribution system or other HVAC system components. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
SC	2	A	3, 9, 12, 14, 16	**Ceiling U-factor**. Reduce the ceiling U-factor from the basecase condition to R-60. The U-factor for this condition shall be taken from ACM Joint Appendix IV. Do not assume field verification for construction quality. Produces a positive compliance margin.	**South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution.
SC	3	A	3, 9, 12, 14, 16	**Wall U-factor**. Increase wall insulation to the equivalent of R-22 in a 2x6 wood framed cavity with R-14 continuous insulation. The U-factor for this condition shall be taken from ACM Joint Appendix IV. Do not assume field verification for construction quality. Produces a positive compliance margin.	**West Glass Area**. Increase west glass area to find the Passing Solution and the Failing Solution.
SC	4	A	12, 14, 16	**Slab F-factor**. Add R-7 slab insulation for climate zones 12 and 14. In climate zone 16, increase slab edge insulation from the basecase R-7 to R-21. Produces a positive compliance margin.	**North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution.
SC	5	A	3, 9, 12, 14, 16	**Fenestration Type**. Replace the basecase fenestration with a super high performance product with a U-factor of 0.25 and a SHGC of 0.40. Produces a positive compliance margin.	**North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution.
SC	6	A	3, 9, 12, 14, 16	**Fenestration Type**. Replace the basecase fenestration with a product that fails to comply with the package D requirements. The replacement product shall have a U-factor of 0.90 and an SHGC of 0.70. Produces a negative compliance margin.	**AFUE**. Increase or reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
SC	7	A	12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution.
SC	8	A	3, 9, 12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**West Glass Area**. Increase west glass area to find the Passing Solution and the Failing Solution.
SC	9	A	3, 9, 12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**North Glass Area**. Increase north glass area to find the Passing Solution and the Failing Solution.
SC	10	A	3, 9, 12, 14, 16	**Exposed Thermal Mass**. Increase the percent of the slab-on-grade that is exposed from the basecase condition of 20% to 40%. Produces a positive compliance margin.	**East Glass Area**. Increase east glass area to find the Passing Solution and the Failing Solution.

Series	*Number*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
SC	11	A	3, 9, 12, 14, 16	**South Overhangs**. Add a two foot projection from the surface of the south glass. Its bottom edge is located six inches above the top of the window. The window is assumed to be 6 ft 6 in. high and the overhang is assumed to extend an infinite distance beyond the sides of the windows (see Figure R5-8). Produces a positive compliance margin.	**South Glass Area**. Increase south glass area to find the Passing Solution and the Failing Solution.
SC	12	A	3, 9, 12, 14, 16	**Building Envelope Sealing**. Reduce the building (SLA) from 4.9 to 2.9 through diagnostic testing and sealing. Produces a positive compliance margin.	**Glass Area**. Increase glass area uniformly on all orientations to find the Passing Solution and the Failing Solution.
SC	13	A	3, 9, 12, 14, 16	**Building Envelope Sealing and Mechanical Ventilation**. The building leakage (SLA) is reduced from 4.9 to 2.9 through diagnostic testing and sealing. In addition, mechanical ventilation is added that provides 80 cfm (0.375 air changes per hour) of continuous ventilation and consumes 20 watts of power continuously. Produces a positive compliance margin.	**Glass Area**. Increase glass area uniformly on all orientations to find the Passing Solution and the Failing Solution.
SC	14	A	3, 9, 12, 14, 16	**Construction Quality**. Assume that the proposed design has been field verified to have quality wall and ceiling insulation quality. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
SC	15	A	9, 12, 14	**Cool Roofs / Radiant Barrier**. Remove the radiant barrier (or equivalent cool roof) from the proposed design. Produces a negative compliance margin.	**SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	16	A	9, 12, 14	**Natural Ventilation**. Change the window types to increase the free ventilation area from the default of 10% of the total window area to 20% of the window area, and assume a 10 ft elevation difference between the air inlet and the outlet. Produces a positive compliance margin.	**SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	17	A	3, 9, 12, 14, 16	**Duct Leakage**. Do not seal the ducts as required by the prescriptive standards. Produces a negative compliance margin.	**SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	18	A	3, 9, 12, 14, 16	**Duct Surface Area.** Through diagnostic verification, reduce duct surface area from the default of 27% of the floor area to 10% of the floor area. Produces a positive compliance margin.	**SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	19	B	9, 12, 14	**Duct Location.** Move the HVAC ducts from the crawlspace (the default for one story, raised floor buildings) to the attic. Produces a negative compliance margin.	**SEER**. Reduce the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	20	A	9, 12, 14	**Duct Insulation.** Reduce the duct R-value from the R-8 prescriptive requirement to R-4.2. Produces a negative compliance margin.	**SEER**. Increase the SEER (using default EER) to find the Passing Solution and the Failing Solution.
SC	21	A	9, 12, 14	**Energy Efficiency Ratio (EER)**. Instead of using the default EER of 10.415 for the default SEER 12 assume an EER of 11.5 with the same SEER of 12). Produces a positive compliance margin.	**SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.
SC	22	A	9, 12, 14	**TXV / Charge Testing**. Do not install a TXV and do not field verify that the split system has the correct refrigerant charge. Produces a negative compliance margin.	**SHGC**. Reduce the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.

Series	Number	Prototypes	Climates	Discrete Modification(s)	Continuous Variable
SC	23	A	9, 12, 14	**Airflow Across Evaporator Coil**. Verify through field verification that there is adequate airflow for compliance credit (400 cfm/ton for a wet coil) across the evaporator coil. Produces a positive compliance margin.	**SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.
SC	24	A	9, 12, 14	**Air Conditioner Fan Power**. Reduce fan power through field verification. The default is 0.51 W/cfm. Reduce this to 0.20 W/cfm. Produces a positive compliance margin.	**SHGC**. Increase the SHGC of the windows on all orientations to find the Passing Solution and the Failing Solution.
SC	25	A	3, 9, 12, 14, 16	**Electric Heat**. Replace the gas furnace and air distribution system in the basecase with electric resistance baseboards (no air distribution or duct losses). In addition, increase the ceiling insulation to R-60. The U-factor for this condition shall be taken from ACM Joint Appendix IV. Do not assume field verification for construction quality. Produces a negative compliance margin.	**Fenestration U-factor**. Reduce the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution.
SC	26	A	9, 12, 14	**Side Fins**. For this test side fins are added to the east and west facades of prototype A. The side fins extend 40 feet from the surface of a window that is assumed to be 10 feet wide. The fins are 5 feet from the edge of the window. The top of the side fins are 20 feet above the top of the window. See Figure R5-9. Sidefins are expected to produce a positive compliance margin.	**SEER**. Vary the SEER (keep EER at the default) to find the passing solution and fail the failing solution.

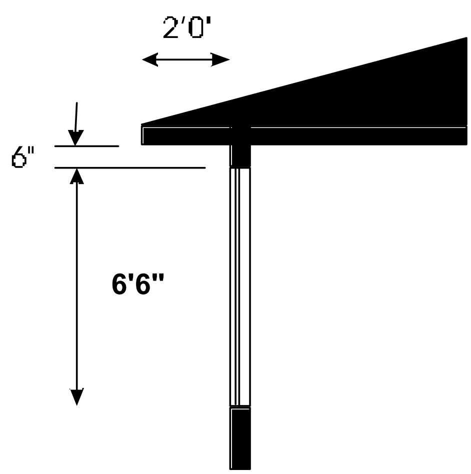

Figure R5-8 – Overhang Characteristics

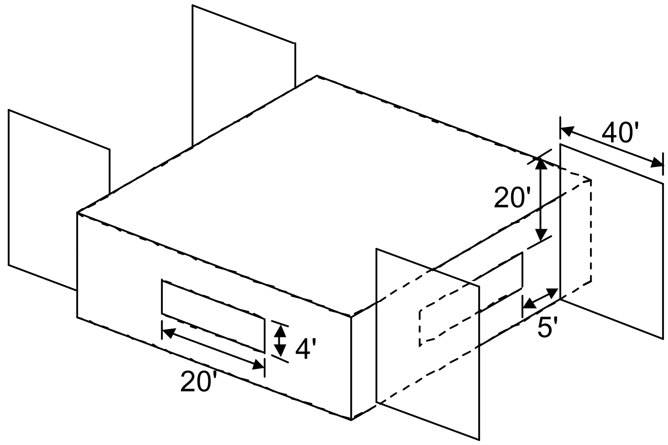

Figure R5-9 – Side Fins for Optional Capabilities Test
The north and south façades are the ones that do not have the sidefins.

Acceptance Criteria

The positive tolerance is the basecase TDV energy for space conditioning plus 3% or 1 kTDV/ft²-y, whichever is greater. The negative tolerance is the basecase TDV energy for space conditioning less 3% or 1 kTDV/ft²-y, whichever is greater. The Energy Commission reference method shall pass the modified basecase when data for the passing solution is entered and fail the modified basecase when data for the failing solution is entered.

In addition to producing estimates that are within the tolerances, the tests are also used to verify that the standard reports are correctly produced, as required in Chapter 2. For instance, many of the discrete modifications trigger measures that shall be listed in the “Special Features and Modeling Assumptions” section of the Certificate of Compliance.

5.2.2 Standard Design Generator Tests (*SD*)

This section describes the standard design tests that shall be performed by the ACM vendor. The standard design tests use the series designation “SD.” ACMs shall automatically create the standard design building, as defined in Chapter 3. The standard design run is made automatically at the same time as the proposed design run, and the results are reported together on the Certificate of Compliance discussed in Chapter 2. The tests described in this section verify that the standard design is correctly defined for the proposed design and that the custom budget is correctly calculated. These tests supplement the SC tests, which also verify certain standard design features.

Prototypes Buildings

The custom budget tests use three prototype buildings as described below.

C Prototype C is a 1,761 ft² , one and two-story, single-family detached home which is widely used to analyze the impact of the standards and the cost effectiveness of measures. Two versions of this prototype are used in the tests. One has a slab floor and one has a raised floor. Details are available from the Energy Commission.

D Prototype D is identical to prototype C, except that it is has a raised floor. Details are available from the Energy Commission.

E Prototype E is an eight-unit, two-story multi-family building. Details are available from the Energy Commission.

Standard Design Equivalent Tests

The standard design equivalent tests are described in Table R5-2. For each of these tests, the standard design equivalent budget and proposed design TDV energy shall equal each other. In addition, the TDV energy shall equal the budget TDV energy for the proposed building.

Table R5-2 – Standard Design Tests

Series	*Number*	*Prototypes*	*Climates*	*Description*
SD	0	A, B	All	**Basecase Prototypes**. These tests were also performed in the SC series. For each of these tests, the standard design and proposed design TDV energy shall be equal. There is no proposed design case for these tests.
SD	1	C	All	**Slab-On-Grade**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using slab-on-grade designs. The "SC01C**" files are run in all 16 climate zones.
SD	2	D	All	**Raised Floor**. The purpose of this test is to verify that the standard design generator correctly defines the standard design for proposed designs using raised floor buildings. The "SC01D**" files are run in all 16 climate zones.
SD	3	E	All	**Multi-Family.** The purpose of this test is to verify that the standard design generator correctly defines the standard design for multi-family buildings. The "SC01E**" files are run in all 16 climate zones.

Neutral Variable Tests

The neutral variable tests are described in Table R5-3. For each of these tests, the compliance margin shall remain within one percent of zero.

Table R5-3 – Neutral Variable Design Tests – Space Conditioning

Series	*Number*	*Prototypes*	*Climates*	*Description*
SD	4	A	3, 9, 12, 14, 16	**Window Area**. Reduce window area from 20% of the floor area to 15% of the floor area. Reduce the size of the window on each façade to 60 ft². Do not change any other features.
SD	5	A	3, 9, 12, 14, 16	**Wall Area.** Increase the gross wall area on each façade from 400 ft² to 600 ft².

5.2.3 Additions and Alternations (AA)

This section describes the tests for alternations and additions that shall be performed by the ACM vendor. The additions and alternations tests use the series designation "AA."

Additions are treated as new buildings except that internal heat gains are allocated on a fractional dwelling unit basis. With the Addition + Existing + Alternation approach, energy credit may be taken for improvements to the existing building. This series of tests exercises the various default assumptions (see Table 3-11 in Section 3.8.4) based on the vintage of the existing building and the various reporting requirements for modeling an addition with an existing building. In addition, these tests verify the proper determination of the energy budget and compliance criteria for an addition with an improved existing building.

Prototype Buildings

The prototype used in these tests consists of an existing building and an addition. The existing building has the same physical configuration as Prototype A but the thermal performance of building envelope components is downgraded to be more typical of older existing buildings. Prototype E (Figure R5-10) has the thermal characteristics of 1977 construction practice and Prototype F has the thermal characteristics of 1989 construction practice. See the Additions and Alternations section of Chapter 3 for details on construction assemblies. Each window is 4 ft high and 20 ft wide centered on the façade. The addition is 12 ft deep by 40 ft long and 10 ft high and covers the whole west side of the existing building.

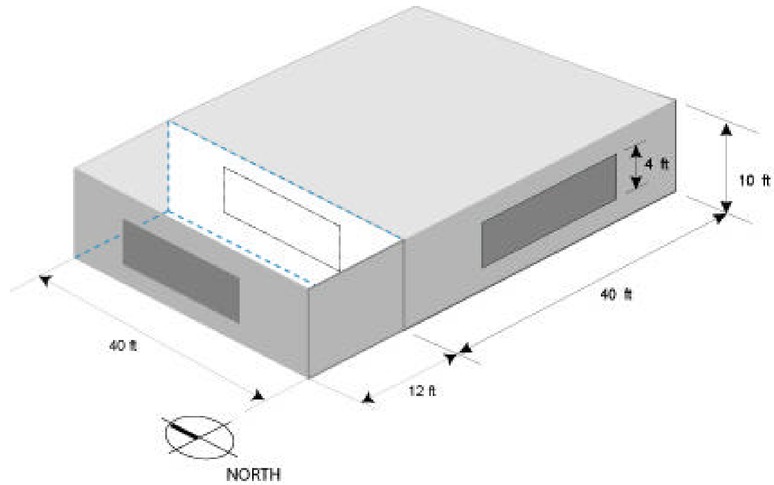

Figure R5-10 – Prototypes E and F

Test Descriptions

These tests are also be used to confirm that reporting requirements are met when modeling an addition with an existing building and that the appropriate budgets have been correctly determined. Two of the three compliance approaches for additions and alternations are evaluated with these tests: the addition-alone approach and the Existing + Addition + Alteration approach. The whole building approach is not evaluated since this is identical to new construction. Table R5-4 describes the tests to perform with the Addition-Alone approach. Table R5-5 describes the tests to perform with the Existing + Addition + Alteration approach.

Table R5-4 – Summary of the Addition-Alone Tests

Series	*Number*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
AA	1	E 1977	3, 9, 12, 14, 16	**Baseline**. The features of the addition shall all exactly meet the prescriptive requirements. The addition is served by an HVAC system in the existing house.	**None**. This is a standard design generator test.
AA	2	E 1977	3, 9, 12, 14, 16	**Increase Glass**. Increase fenestration area on the west side of the addition to 144 ft². This discrete change will fail compliance because the glass area exceeds 20% of the floor area.	**Fenestration Area U-factor**. Reduce the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution.
AA	3	F 1989	3, 9, 12, 14, 16	**New HVAC**. Install a separate HVAC split system gas/electric system for the addition that has an SEER of 14 and an EER of 13. This will create a positive compliance margin.	**Fenestration U-factor**. Increase the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution.

Table R5-5 – Summary Existing + Addition + Alternation Tests

Series	Number	Prototypes	Climates	Discrete Modification(s)	Continuous Variable
EA	1	E 1977	3, 9, 12, 14, 16	**Baseline**. The features of the addition shall all exactly meet the prescriptive requirements. The addition is served by an HVAC system in the existing house. Remove 80 ft² from the existing west wall and include 80 ft² with the addition (no net increase in glass area)	**None**. This is a standard design generator test.
EA	2	E 1977	3, 9, 12, 14, 16	**Increase Glass**. Increase fenestration area on the west side of the addition to 144 ft². This discrete change will fail compliance because the glass area exceeds 20% of the floor area.	**Fenestration U-factor**. Reduce the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution.
EA	3	F 1989	3, 9, 12, 14, 16	**New HVAC**. Install a separate HVAC split system gas/electric system for the addition that has an SEER of 14 and an EER of 13. This will create a positive compliance margin.	**Fenestration U-factor**. Increase the fenestration U-factor in the addition to find the Passing Solution and the Failing Solution.

Acceptance Criteria

For each test, the Energy Commission reference method shall pass the addition plus existing building when data for the passing solution is entered and fail the addition plus existing building when data for the failing solution is entered. The positive tolerance is the TDV space conditioning energy for the basecase plus 3% or 1 kBtu/ft²-y, whichever is greater, and the negative tolerance is also 3% or 1 kBtu/ft²-y, whichever is greater. In addition to producing estimates that are within the tolerances, the Energy Commission will also verify that the correct performance factors are used, based on the vintage of the existing building, and that the standard reports are correctly produced, as required in Chapter 2.

5.3 Water Heating Tests (WH)

This section describes the water heating tests that shall be performed by the ACM vendor. The water heating tests use the series designation “WH”. The water heating tests are defined in a similar manner as the space conditioning tests, except that the tests are performed relative to a water heating system, not whole building TDV energy. See the Overview section of this chapter for a description of the procedures. For the water heating tests, only the TDV energy for water heating is considered in the comparison.

5.3.1 Prototype Systems

Two prototype water heating systems are used. The first is a system which serves the single family home represented by space conditioning prototype C (the water heating system also uses the “C” designation). The second is a system that serves the multi-family apartment building represented by prototype E (this uses the “E” designation). More information on the buildings served is provided above in the prototype descriptions for the space conditioning tests. The water heating systems for the two prototypes are described in Table R5-6.

Table R5-6 – Base Case Water Heating Systems

Prototype	Prototype C	Prototype E
Building Information		
Dwelling Units	1	16
Total Building Area	1,761 ft²	11,616 ft²
Average Dwelling Unit Size	1,761 ft²	726 ft²
Water Heating Equipment		
Number of Water Heaters	1	4
Water Heater Type	Storage Gas (SG)	Storage Gas (SG)
Energy Factor	0.575	0.480
Tank Size	50	4 @ 100
Distribution System	Standard (PIK)	Recirculation with timer controls
Multi-Family Recirculation System		
Linear Feet of Pipe (Note 1)	n.a.	200
PF Outdoor Air	n.a.	0.10
PF Ground	n.a.	0.20
PF Conditioned or semi-conditioned air within the building envelope	n.a.	0.70
Pipe Diameter for Recirculation System	n.a.	1.5 in.
Recirculation Pipe Insulation	n.a.	1.0 in.
Pump Size (brake horsepower)	n.a.	½ hp
Pump Motor Efficiency	n.a.	0.85

Note 1. Total Linear feet used for recirculation between dwelling units (input to Section 3.5). PF is the fraction of the total linear feet that is used either outside, in the ground, or in the conditioned or semi-conditioned air within the building envelope, as defined in Section RG3.5.

5.3.2 Accuracy Tests (WH)

As described in the Overview of this chapter, the ACM vendor shall find the passing and failing solution for each test described in Table R5-7. The Energy Commission reference method shall then pass the modified basecase when data for the passing solution is entered and fail the modified basecase when data for the failing solution is entered. The acceptance criteria shall be satisfied for all tests. The water heating tests use a 2% passing tolerance and a 2% failing tolerance, or 1.0 kTDV/ft²-y, whichever is greater.

Table R5-7 – Accuracy Tests – Water Heating

Type	*Test*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
WH	0	C, E	All	None	None
WH	1	C, E	3, 9, 12, 14, 16	**Electric Storage Water Heater.** Change the water heater type from Gas Storage to Electric Storage. Use an Energy Factor of 0.91 for prototype C and 0.87 for E. This produces a negative compliance margin.	**Solar Savings Fraction (SSF).** Increase the SSF to find the passing and failing solutions.
WH	2	C, E	3, 9, 12, 14, 16	**Electric Instantaneous Water Heater.** Change the water heater type from gas storage to electric Instantaneous and use a point of use (POU) distribution system. This produces a negative compliance margin.	**Solar Savings Fraction (SSF).** Increase the SSF to find the passing and failing solutions.
WH	32	C	3, 9, 12, 14, 16	**Distribution Type.** Change the distribution system from the default to pipe insulation on all lines (PIA) system. This produces a positive compliance margin.	**Energy Factor.** Reduce the EF for the proposed building until the passing and failing solutions are reached.
WH	4	E	3, 9, 12, 14, 16	**Recirculation Control.** Add temperature and timer controls (RTmTp) for the recirculating system. This produces a positive compliance margin.	**Energy Factor (EF).** Reduce the EF to find the passing and failing solutions.
WH	5	E	3, 9, 12, 14, 16	**Large Storage Water Heater.** Change water heater type to a 400 gallon large gas storage, SBL = 0.1, thermal (recovery) efficiency= 0.75.	**Thermal Efficiency.** Decrease or increase thermal efficiency (recovery efficiency or AFUE) until the passing and failing solutions are reached.
WH	6	E	3, 9, 12, 14, 16	**Recirculation Piping Insulation.** Increase recirculation piping insulation from 1 in. to 1.5 in. This produces a positive compliance margin.	**Energy Factor.** Reduce the energy factor to find passing and failing solutions.
WH	7	C	3, 9, 12, 14, 16	**Number of Water Heaters.** Use 2 water heaters for the single residence; both are the same size and performance as the basecase. This will produce a negative compliance margin	**Energy Factor.** Increase the energy factor of both water heaters together to find passing and failing solutions.
WH	8	E	3, 9, 12, 14, 16	**Pump Controls.** Baseline assumes timer pump controls. Change to no pump control. This produces a negative compliance margin.	**Energy Factor.** Increase the energy factor of both water heaters together to find passing and failing solutions.

5.3.3 Standard Design Tests (WD)

This section describes a series of tests that verify that the standard design is being correctly defined for water heating systems. The acceptance criteria for these tests are different from the accuracy tests. For this series of tests, a change is defined, which according to the rules for defining the standard design should be neutral. Being neutral means that the change is reflected for both the standard design and the proposed design. The compliance margin shall be within plus or minus 2% of the standard design TDV energy for water heating (space conditioning is not considered). In addition, TDV energy for water heating shall move in the direction indicated in each test description.

Standard Design Equivalent Tests

For water heating the standard design equivalent tests consist of running the basecase water heating systems in all 16 climates. For each case, the standard design TDV energy shall equal the proposed design TDV energy. See Table R5-8.

Table R5-8 – Standard Design Equivalent Tests – Water Heating

Type	*Test*	*Prototypes*	*Climates*	*Discrete Modification(s)*	*Continuous Variable*
WD	0	C, E	All	None	None

Neutral Variable Tests

The neutral variable tests are shown in Table R5-9. For these tests, the compliance margin shall remain at zero, unchanged.

Table R5-9 – Neutral Variable Tests – Water Heating

Type	*Test*	*Prototypes*	*Climates*	*Discrete Modification(s)*
WD	1	C	3, 9, 12, 14, 16	**House Size**. Increase house size to 2,500 ft². TDV energy for both the *Standard Design* and the *Proposed Design* shall increase.
WD	2	C	3, 9, 12, 14, 16	**House Size**. Increase house size to 3,500 ft². The TDV energy for both the *Standard Design* and the *Proposed Design* shall equal the TDV energy for test 1.
WD	3	D	3, 9, 12, 14, 16	**Pipe Length**. Increase recirculation piping length to 400 ft. TDV energy for both the *Standard Design* and the *Proposed Design* shall increase.
WD	4	D	3, 9, 12, 14, 16	**Pipe Location**. Move all the piping outdoors. PF ground and plenum become zero and PF outdoors becomes 1.00. TDV energy for both the *Standard Design* and the *Proposed Design* shall increase.
WD	5	D	3, 9, 12, 14, 16	**Individual Water Heaters.** Replace the central water heating system with individual water heaters in each dwelling unit, which meet the basecase specification for single-family homes (see Table R5-6)

6. Optional Capabilities Tests

6.1 Overview

This chapter of the Manual explains the tests that must be performed in order for residential ACMs to be approved for optional capabilities. See the Overview section of Chapter 5 for details. There are two sets of optional capabilities. The first are for space conditioning and include hydronic heating systems, combined (with the water heater) hydronic heating, zonal control of space temperatures, sunspaces, side fins and exterior mass walls. The second set of capabilities relate to solar systems used for water heating applications. At this time, photovoltaic systems are not an optional capability.

6.2 Optional Space Conditioning Capabilities

6.2.1 Summary of Tests

The optional capabilities tests for space conditioning are summarized in Table R6-1. These tests use the same labeling scheme, test procedures, and prototypes as the minimum modeling capabilities (see Chapter 5).

Table R6-1 – Summary of the Optional Space Conditioning Tests

Type	*Test*	*Prototypes*	*Climates*	*Optional Capability (Discrete Modification(s))*	*Continuous Variable*
OC	1	A	3, 9, 12, 14, 16	**Dedicated Hydronic.** Replace the gas furnace and air distribution system with a gas boiler with hydronic baseboards and fan coils. See detailed description below. Produces a positive compliance margin.	**Fenestration U-factor**. Increase the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution.
OC	2	A	3, 9, 12, 14, 16	**Combined Hydronic, Gas Water Heater**. A 75 gallon storage gas water heater is used for both space conditioning and water heating. Hot water baseboards are used for heat distribution. Insulated pipes are used in unconditioned space.	**Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution.
OC	3	A	3, 9, 12, 14, 16	**Combined Hydronic, Electric Resistance Water Heater**. An electric water heater is used for both space conditioning and water heating and air is distributed through a fan coil system that delivers air to ducts located in an attic.	**Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution.
OC	4	A	3, 9, 12, 14, 16	**Combined Hydronic, Heat Pump Water Heater**. An electric heat pump is used for both space conditioning and water heating. Distribution is provided through hot water baseboards. All pipes are located within conditioned space.	**Fenestration U-factor**. Vary the U-factor of the fenestration to find the passing solution and the failing solution.
OC	5	B	3, 9, 12, 14, 16	**Control Vent Crawlspace**. See detailed description below. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
OC	6	A	3, 9, 12, 14, 16	**Zonal Control**. See detailed description below. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
OC	7	A	3, 9, 12, 14, 16	**Attached Sunspace**. See detailed description below. Produces a positive compliance margin.	**AFUE**. Reduce the heating equipment AFUE to find the Passing Solution and the Failing Solution.
OC	8	A	3, 9, 12, 14, 16	**Exterior Mass Walls**. See detailed description below. Produces a negative compliance margin.	**Wall R-value**. Increase the interior wall R-value to find the Passing Solution and the Failing Solution.
OC	9	A	3, 9, 12, 14, 16	**Gas Absorption Cooling.** Replace the basecase cooling system with an absorption gas cooling system with a COP of 3.3. Produces a positive compliance margin	**Fenestration U-factor**. Increase the fenestration U-factor on all orientations to find the Passing Solution and the Failing Solution.

6.2.2 Dedicated Hydronic Systems

Measure Description

Dedicated hydronic systems have boilers or other heating devices which produce hot water that is distributed through the building for heating. The system is commonly used in other areas of the country. Its use in California is limited. Heat is transferred through the building by water instead of air. Terminal heating units include fan coils, baseboards, radiant floors, or radiant ceilings. If large fan coils are used that distribute warm air through a conventional air distribution system, then the losses of the duct system must be accounted for in the same manner as gas furnaces.

Algorithms and Modeling Assumptions

Dedicated hydronic systems are modeled in a manner similar to a gas furnace, but the AFUE of the boiler is adjusted to account for pipes located outside the conditioned space. The ACM vendor shall include inputs for pipes located in unconditioned spaces. Inputs shall include the pipe length, diameter and insulation, as described in Chapter 2.

Equation R6-1

$$AFUE_{eff} = AFUE - \frac{PL}{RI}$$

Where

$AFUE_{eff}$ = The effective AFUE of the gas boiler that is providing space heat (unitless).

AFUE = The rated AFUE of the boiler (unitless).

PL = Annual Pipe losses (kBtu/h). This may be assumed to be zero when less than 10 feet of the piping (plan view) is located in unconditioned space. Pipe losses are calculated using the procedures described below.

RI = The rated input of the gas water heater (kBtu/h). This is available from the Energy Commission appliance directory and other sources.

If heat is distributed with a fan coil, then the energy of the fan shall be accounted for in the same manner as for furnaces. The default fan energy is 0.005 Wh/Btu of heat delivered by the fan coil (not the entire heating system).

Hydronic systems are permitted when the AFUE is known and can be entered. When water heaters are used in hydronic systems for space heating alone (a separate water heater for domestic service), the water heater functions as a boiler and is required by NAECA to have a minimum AFUE of 0.80. The AFUE of a water heater if tested as a boiler would be approximately equal to the average of the EF and the RE, and will generally not meet the minimum NAECA requirement. Water heaters proposed for use in hydronic systems for space heating only must be tested as a boiler using the DOE AFUE and appropriate safety standard test procedures.

Test Description

For prototype A, the basecase heating system, consisting of a gas furnace and a forced air distribution system, is replaced with a dedicated hydronic system. The boiler has an AFUE of 85%. Twenty (20) ft of insulated pipe are located in unconditioned space. Heat is distributed with combination of fan coils (20 kBtu/h) and hydronic baseboards (40 kBtu/h). Water is circulated through the hydronic loop by a 1/8 hp pump. The pump motor meets the minimum efficiency requirements of the California appliance efficiency standards. Substituting this system will produce a positive compliance margin. The fenestration U-factor is then reduced to find the passing solution and the failing solution, according to the procedures described in Chapter 5. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The ACM vendor must also demonstrate that the software correctly produces the standard design. This requires that the vendor create a standard design equivalent building that matches the standard design for the system described above. When the standard design equivalent building is entered into the candidate ACM, the proposed design and standard design TDV energy must equal each other. The standard design equivalent energy must also equal the standard design energy for the test case.

6.2.3 Combined Hydronic Space/Water Heating

Measure Description

Combined hydronic space/water heating is a system whereby a water heater is used to provide both space heating and water heating. Dedicated hydronic space heating systems are also an optional capability covered in

Section 6.2.2. Space heating terminals may include fan coils, baseboards, and radiant surfaces (floors, walls or ceilings).

Algorithms and Modeling Assumptions

For combined hydronic systems, the water heating portion is modeled in the normal manner. For space heating, an effective AFUE is calculated for gas water heaters. For electric water heaters or heat pumps, an effective HSPF is calculated. The procedures for calculating the effective AFUE or HSPF are described below.

When a fan coil is used to distribute heat, the fan energy and the heat contribution of the fan motor must be considered. The algorithms for fans used in combined hydronic systems are the same as those used for gas furnaces and are described in Chapter 4.

If a large fan coil is used and air distribution ducts are located in the attic, crawlspace or other unconditioned space, then the efficiency of the air distribution system must be determined using methods consistent with those described in Chapter 4. Duct efficiency is accounted for when the distribution type is "ducts."

Storage Gas Water Heater

When storage gas water heaters are used in combined hydronic applications, then the effective AFUE is given by the following equation.

Equation R6-2

$$AFUE_{eff} = RE - \frac{PL}{RI}$$

Where

$AFUE_{eff}$ = The effective AFUE of the gas water heater in satisfying the space heating load.

RE = The recovery efficiency of the gas water heater. A default value of 0.76 may be assumed if the recovery efficiency is unknown. However, this value is generally available from the Energy Commission appliance directory.

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space (see Equation R6-6).

RI = The rated input of the gas water heater (kBtu/h). This is available from the Energy Commission appliance directory.

Storage Electric Water Heater

The HSPF of storage water heaters used for space heating in a combined hydronic system is given by the following equations.

Equation R6-3

$$HSPF_{eff} = 3.413\left[1 - \frac{PL}{3.413 kWi}\right]$$

Where:

$HSPF_{eff}$ = The effective HSPF of the electric water heater in satisfying the space heating load.

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements are located in unconditioned space (see Equation R6-6).

kWI = The kilowatts of input to the water heater.

Heat Pump Water Heater

The HSPF of heat pump water heaters used for space heating in a combined hydronic system is given by the following equations. If the system has a fan coil, the $HSPF_{eff}$ is used. $HSPF_{w/o\_fan}$ is used if there is no fan coil.

Equation R6-4

$$HSPF_{eff} = 3.413\left(\frac{RE_{hp}}{CZ_{adj}} - \frac{PL}{3.413kWi}\right)$$

where

$HSPF_{eff}$ = The effective HSPF of the heat pump water heater in satisfying the space heating load.

CZ_{adj} = The climate zone adjustment (see Table RG-7).

PL = Pipe losses (kBtu/h). This can be assumed to be zero when less than 10 feet of the piping between the water heater storage tank and the fan coil or other heating elements is located in unconditioned space (see Equation R6-6).

kWI = The kilowatts of input.

RE_{hp} = The recovery efficiency of the heat pump water heater. Equation R6-5 may be used as a default if the recovery efficiency is not known.

Equation R6-5

$$RE_{hp} = \frac{1}{\frac{1}{EF_{DOE}} - 0.1175}$$

where

EF_{DOE} = The energy factor of the heat pump water heater when tested according to the DOE test procedure.

Pipe Losses

Pipe losses must be considered when pipes between the water heater storage tank and the fan coil or other heating element are located in unconditioned space. To simplify compliance, pipe losses can be ignored when no more than ten feet of pipe (in plan view) is located in unconditioned space. Hourly pipe loss rates (PLR) are given either from Equation R6-7 or from Table R6-2.

Equation R6-6

$$PL = \sum_{i=1}^{n} \frac{FT_i \times PLR_i}{8760}$$

PL = Hourly pipe loss (kBtu/h).

PLR_i = The annual pipe loss rate per foot of length for the i^{th} pipe (kBtu/y-ft).

FT_i = The length in feet of the i^{th} pipe located within unconditioned space. Can be assumed to be zero if less than ten feet in plan view.

n = The number of unique pipe size or insulation conditions.

The annual pipe loss rate per foot of length (PLRi) is calculated from the following equation

Equation R6-7

$$PLR_i = 8.76 \left(\frac{T_s - T_a}{\frac{\ln\left(\frac{D_{io}}{D_{po}}\right)}{2 \pi Ki} + \frac{1}{\pi \, ha \, D_{io}}} \right)$$

where

8.76 = Conversion factor from Btu/h to kBtu/y

T_s = Supply Temperature. This is assumed to be a constant 135 F.

T_a = Ambient Temperature. This is assumed to be 60.3 in all California climate zones.

D_{io} = Outside diameter of insulation. ft (actual not nominal).

D_{po} = Outside diameter of pipe, ft (actual not nominal).

Ki = Insulation conductivity, constant 0.023 Btu/h-ft-F

ha = Air film coefficient, constant 1.65 Btu/h-ft²-F

Table R6-2 – Annual Pipe Loss Rates (kBtu/y-ft)

	Insulation Thickness		
Nominal Pipe Size	1/2 inch	¾ inch	1 inch
1/2 inch	71.6	60.9	54.2
3/4 inch	91.1	75.8	66.6
1 inch	109.9	90.1	78.1
1 - 1/2 inch	146.7	117.5	100.3
2 inch	182.9	144.3	121.7

Test Description

The tests for combined hydronic systems are based on modifications to prototype A. Three different systems are added as discrete modifications. The test systems are described in Table R6-3

Table R6-3 – Combined Hydronic System Specifications

		Test Number		
		OC2A	OC3A	OC4A
Water Heater Type		SG	SE	HP
Recovery Efficiency	Unitless	0.76	n.a.	n.a.
Rated Input	Btu/h	60,000	n.a.	n.a.
Rated Input	KW	n.a.	5.00	n.a.
Wpump	W	n.a.	60.0	n.a.
EF	Unitless	n.a.	n.a.	2.00
Pipe Length in Unconditioned Space	Ft	100.0	n.a.	n.a.
Annual Pipe Loss Rate	kBtu/y-ft	71.6	n.a.	n.a.

For this series of tests, only the TDV energy for space conditioning is considered. The combined hydronic systems described above are added to the Prototype A building to replace the gas furnace. The ACM vendor shall change the fenestration U-factor on all orientations of the prototype to find the passing solution and the failing solution. The Energy Commission reference method shall pass the passing solution and fail the failing solution.

In addition, the ACM vendor shall demonstrate that the software correctly defines the standard design for combined hydronic. This is achieved by creating and running the standard design equivalent building. For the standard design equivalent building, the TDV energy for the proposed design and the standard design must be equal. The standard design equivalent TDV energy must also equal the TDV energy for the standard design case of this test.

6.2.4 Controlled Ventilation Crawl Spaces (CVC)

Measure Description

A controlled ventilation crawlspace has insulation installed in the side walls of the crawlspace, instead of in the floor that separates conditioned space from the crawlspace. In addition, special dampers are used to provide the required ventilation for the crawlspace which open in the summer and close in the winter.

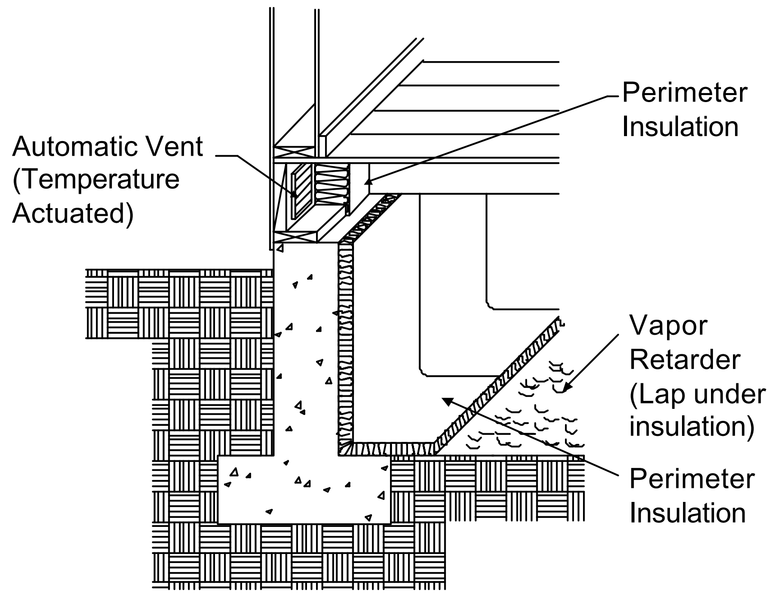

Figure R6-1 – Section at Crawlspace Perimeter

Algorithms and Modeling Assumptions

CVC requires that the ACM have the capability of modeling two thermal zones. The house itself if modeled as a conditioned zone and the crawlspace is modeled as an unconditioned zone.

Test Description

To test this optional capability the ACM vendor shall model prototype B in climate zones 3, 9, 12, 14, and 16. The CVC to be modeled shall have the following features:

- The CVC unconditioned zone has an exterior perimeter length and floor area (i.e., the ground area) equal to the prototype building B. Crawlspace volume is 3,467 ft^3.
- CVC infiltration is modeled using the air changes per hour method and uses 0.22 air changes per hour.
- The floor separating the crawl space from conditioned space is an inter-zone boundary. 400 ft^2 of this floor has a U-value of 0.342, representing an uninsulated, uncarpeted floor, and the remainder has a U-value of 0.199, representing an uninsulated, carpeted floor.
- Insulation that meets the floor insulation requirements used for compliance is placed in the perimeter walls of the crawl space.
- The crawl space vents are modeled with automatic seasonally operated louvers to minimize ambient conditions within the crawl space. When the building is in a heating mode, the vents are closed (inlet and outlet are zero). When the building is in a cooling mode, the vents are open and the total vent area is 1/150 of the crawlspace floor area or 10.67 ft^2. Half of this is inlet and half outlet.
- The ventilation height difference is zero. Only wind effects apply. Wind speed is reduced to 25% of that on the weather tape to account for ground level conditions.
- Heat capacity in the crawlspace is 1.4 Btu/F-ft^2.

This system is expected to produce a positive compliance margin. The heating equipment AFUE is then reduced to find the passing solution and the failing solution. The Energy Commission reference method must pass the passing solution and fail the failing solution. Several eligibility criteria apply for CVC.

In addition, the vendor shall demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. The vendor shall create and run the standard design equivalent building for climate zone 12. The proposed design and standard design TDV energy for the be equal. The TDV energy from the standard design equivalent must also equal the standard design TDV energy for this test.

Eligibility Criteria

Drainage. Proper enforcement of site engineering and drainage, and emphasis on the importance of proper landscaping techniques in maintaining adequate site drainage, is critical.

Ground Water And Soils. Local ground water tables at maximum winter recharge elevation should be below the lowest excavated site foundation elevations. Sites that are well drained and that do not have surface water problems are generally good candidates for this stem-wall insulation strategy. However, the eligibility of this alternative insulating technique is entirely at the building officials' discretion. Where disagreements exist, it is incumbent upon the applicant to provide sufficient proof that site drainage strategies (e.g., perimeter drainage techniques) will prevent potential problems.

Ventilation. All crawl space vents must have automatic vent dampers to receive this credit. Automatic vent dampers must be shown on the building plans and installed. The dampers should be temperature actuated to be fully closed at approximately 40°F and fully open at approximately 70°F. Cross ventilation consisting of the required vent area reasonably distributed between opposing foundation walls is required.

Foam Plastic Insulating Materials. Foam plastic insulating materials must be shown on the plans and installed when complying with the following requirements:

- Fire Safety—UBC Section 1712(b)2. Products shall be protected as specified. Certain products have been approved for exposed use in under floor areas by testing and/or listing.
- Direct Earth Contact—Foam plastic insulation used for crawl-space insulation having direct earth contact shall be a closed cell water resistant material and meet the slabedge insulation requirements for water absorption and water vapor transmission rate specified in the mandatory measures.

Mineral Fiber Insulating Materials

- Fire Safety—UBC Section 1713(c). "All insulation including facings, such as vapor barriers or breather papers installed within ... crawl spaces ... shall have a flame-spread rating not to exceed 25 and a smoke density not to exceed 450 when tested in accordance with UBC. Standard No. 42-1." In cases where the facing is also a vapor retarder, the facing shall be installed to the side that is warm in winter.
- Direct Earth Contact—Mineral fiber batts shall not be installed in direct earth contact unless protected by a vapor retarder/ground cover.

Vapor Barrier (Ground Cover). A ground cover of 6 mil (0.006 inch thick) polyethylene, or approved equal, shall be laid entirely over the ground area within crawl spaces.

- The vapor barrier shall be overlapped six inches minimum at joints and shall extend over the top of pier footings.
- The vapor barrier should be rated as 1.0 perm or less.
- The edges of the vapor barrier should be turned up a minimum of four inches at the stem wall.
- Penetrations in the vapor barrier should be no larger than necessary to fit piers, beam supports, plumbing and other penetrations.
- The vapor barrier must be shown on the plans and installed.

Studies show that moisture conditions found in crawl spaces that have minimal ventilation do not appear to be a significant problem for most building sites provided that the crawl-space floors are covered by an appropriate vapor barrier and other precautions are taken. The Energy Commission urges building officials to carefully evaluate each application of this insulating technique in conjunction with reduced ventilation because of the potential for adverse effects of surface water on crawl-space insulation that could negate the energy savings predicted by the procedure.

6.2.5 Zonal Control

Measure Description

Zonal control is one of the optional capabilities based on the ability of an ACM to model more than one conditioned thermal zone at the same time. With zonal control, the sleeping and living areas are modeled separately, each with its own separate thermostat schedule and internal gain assumptions. The specifications for zonal control are detailed in Chapter 4. Key features are discussed below.

Algorithms and Modeling Assumptions

The thermostat schedules are in Chapter 4 Table R4-1. An alternate set of internal gain schedules is used: one for the living areas of the house and one for the sleeping areas. Both standard schedules and schedules for zonal control are shown in Chapter 4.

Test Description

For this test, prototype A is divided into living and sleeping zones as shown in Figure R6-2. The boundary between the zones consists of a wall with U-value of 0.29 and net area of 360 ft^2. The wall contains an uncloseable opening of 40 ft^2, modeled with a U-value of 20.0 Btu/h-ºF-ft².

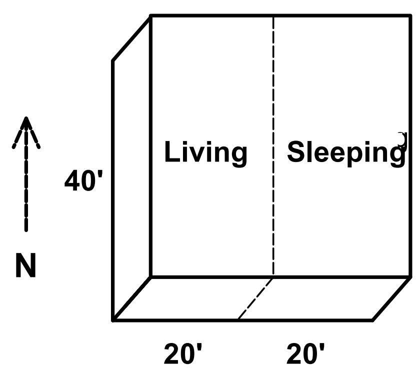

Figure R6-2 – Zoning the Prototype Building

Zonal control is added to prototype A as the discrete modification. The heating equipment AFUE is then reduced to find the passing solution and the failing solution as defined in Chapter 5. This test is performed in climate zones 3, 9, 12, 14, and 16. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The vendor shall also demonstrate that the ACM correctly defines the standard design building and calculates the custom budget correctly. The vendor shall create and run a standard design equivalent building in climate zone 12. In the standard design equivalent building, the proposed design and standard design TDV energy must equal each other. The standard design equivalent TDV energy must also equal the standard design energy for this test.

6.2.6 Sunspaces

Measure Description

A sunspace is a passive solar system consisting of an unconditioned space facing south or near south. The sunspace has a great deal of fenestration that collects solar energy and stores the energy in thermal mass elements such as a slab floor. The ACM must be capable of modeling two thermal zones in order for the sunspace feature to be approved.

Algorithms and Modeling Assumptions

Sunspaces shall be modeled as a separate, unconditioned thermal zone. An interzone vent separating the house from the sunspace is controlled to open only when temperature (T) conditions are $T_{house} < T_{desired}$ and $T_{sunspace} > T_{house}$ (in heating mode).

Assumptions for infiltration, heat capacity, solar gain targeting, and zone thermostat temperature settings vary from the conditioned zone. Internal gains in the sunspace are assumed to be zero. Sunspace zone infiltration is modeled using the air changes per hour method and the same infiltration of 0.50 air changes per hour. There are no restrictions on targeting solar gains that enter unconditioned spaces such as sunspaces.

Test Description

For this test, an unconditioned sunspace is added to the south side of Prototype A as illustrated in Figure R6-3 and Figure R6-4. The wall and window separating the sunspace and the house remain the same as in the base case, but the surfaces and vent openings of this wall are changed from exterior types to interzone types. The performance characteristics of sunspace envelope components are the same as for the basecase prototype. Total vent area is assumed to be 40 ft^2 with an eight foot height difference

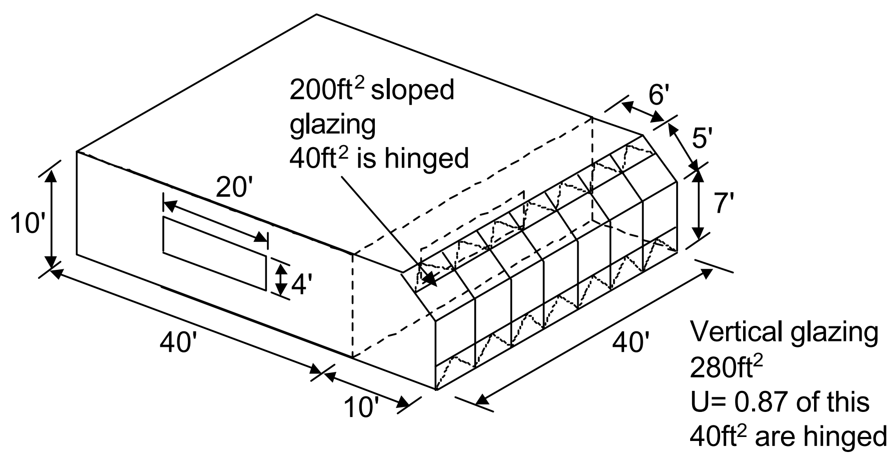

Figure R6-3 – Sunspace Prototype

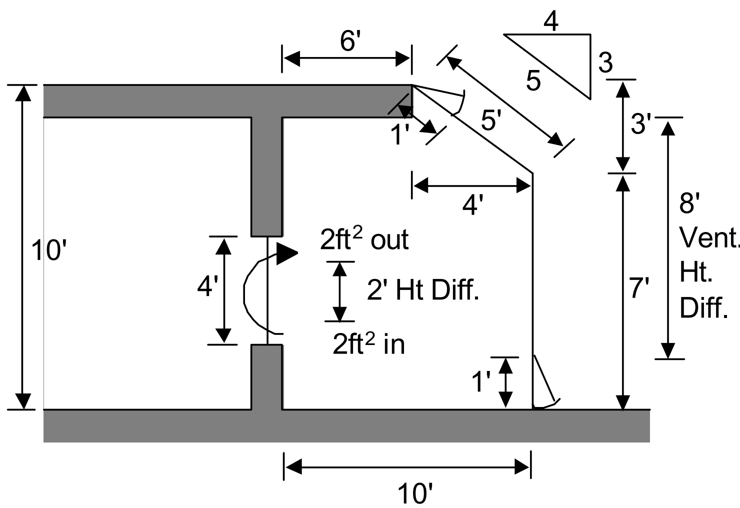

Figure R6-4 – Sunspace Section

The vendor must find the passing solution and failing solution in climates 3, 9, 12, 14, and 16 by varying the heating equipment AFUE. The Energy Commission reference method shall pass the passing solution and fail the failing solution.

The vendor shall also demonstrate that the ACM correctly defines the standard design building and calculates the space conditioning custom budget. The vendor shall create and run a standard design equivalent building for climate zone 12. The standard design equivalent proposed design TDV energy must equal the standard design equivalent standard design TDV energy. These values shall also equal the standard design TDV energy for this test.

6.2.7 Exterior Mass Walls

Measure Description

Exterior mass walls are walls that are built with a heavy material that absorbs heat as the sun strikes it and releases the heat into the conditioned space after a period of time. Thermal mass has the effect of both dampening and delaying heat transfer.

Algorithms and Modeling Assumptions

The ACM must have the capability to model heat storage in exterior walls. The ACM must accept inputs on the thermal storage capacity of walls. For the Energy Commission reference method, this input is heat capacity (HC) which is entered as Btu/ºF-ft². However, ACMs may take the input in other ways acceptable to the Energy Commission.

Test Description

The test for exterior mass walls is made using prototype A in five climate zones: 3, 9, 12, 14, and 16. All of the exterior walls of the building are assumed to be of mass construction: The mass is assumed to be 12 inches thick with a volumetric heat capacity of 10 Btu/F-ft³ and a conductivity of 1.064. The outside surface of the mass wall is modeled with a U-value of 2.63 (R = 0.38) to approximate the effect of an air film. Insulation is assumed to be on the inside surface of the wall. The ACM vendor shall find the passing solution and the failing solution by varying the R-value of the interior insulation. The Energy Commission reference method must pass the passing solution and fail the failing solution.

The ACM vendor shall also demonstrate that the ACM correctly defines the standard design building and calculates the custom budget. The ACM vendor shall create and run a standard design equivalent building for climate zone 12. For the standard design equivalent building, the TDV energy for both the standard design and proposed design cases must be equal. They must also equal the TDV energy for the standard design case in this test.

6.2.8 Gas Cooling

Measure Description

Gas cooling provides an opportunity to reduce peak electric demand. With gas absorption, a chemical process is used to provide cooling.

As a minimum capability, ACMs must be able to accept a COP input, and report the use of gas cooling in the *Special Features and Modeling Assumptions* section of the reports. The ACM user shall also attach manufacturer's equipment specifications showing the COP95, CAP95 and PPC of the equipment.

Algorithms and Modeling Assumptions

Test Description

To determine the accuracy of modeling cooling the ACM vendor shall perform the test listed in Table R6-1. The passing and failing solutions are determined by varying the fenestration U-factor.

6.3 Solar Thermal Water Heating

6.3.1 Overview

This section describes the acceptable methods for calculating the solar savings multiplier (SSM). Two methods are provided here and ACMs can become certified for one or both.

- The first method has limited scope. It may only be used for water heating systems serving individual dwelling units. In addition the solar system has to be rated by the Solar Rating and Certification Corporation (SRCC) with the OG 300 method.
- The second method is more general in scope and may be used for any active solar water heating systems in single family or multi-family buildings.

Energy benefits of solar water heating systems shall be calculated using the procedures described in ACM RG-2005. When a credit is taken for nondepletable energy, the ACM standard input reports must flag this and include a statement in the *Special Features and Modeling Assumptions* section of the reports. The ACM user must also attach SRCC documentation for the system or collectors used and either Commission approved worksheets if the OG 300 method is used or an F-Chart computer run printout if the second method is used.

6.3.2 Integration in ACMs

Solar water heating calculation procedures may be integrated in residential ACMs or they may be stand-alone calculation procedures. The descriptions, algorithms, and test procedures described in this section apply to either case. Contact the Energy Commission for information on how to obtain approval of a stand-alone solar water heating calculation procedure.

6.3.3 Water Heating Systems for Individual Dwellings Rated with the OG 300 Procedure

Measure Description

Residential solar systems can include many types of systems. The simplest system is the integrated collector storage (ICS) system which is basically a dark colored tank mounted behind glazing. Thermosiphon systems have a storage tank mounted above the collectors so that the fluid (usually water) can circulate naturally as it is heated in the collectors. Forced circulation systems use a pump to circulate a fluid from the storage tank to the collector. For forced circulation systems, the collectors may be located remotely from the storage tank.

All of these residential scale solar systems are rated by the Solar Rating and Certification Corporation (SRCC). The SRCC OG 300 procedure tests a complete system put together by the manufacturer, including the collectors, the pumps, controls, storage tanks and backup system (SRCC refers to the backup system as the auxiliary system). The OG 300 procedure uses the TRNSYS computer program to calculate the rating for the system as a whole and produces a Solar Energy Factor (SEF). The SEF is a unitless term and is meant to be compared to the energy factor (EF) published for conventional water heaters. Since the rated system includes the backup water heater, the SEF depends on whether the system was rated with electric or gas backup. It also accounts for the efficiency of the backup system. The SRCC publishes data on all systems and collectors hat have been rated.

Algorithms and Modeling Assumptions

Modeling assumptions and algorithms are documented in ACM Appendix RG-2005.

Eligibility Criteria

In order to use the OG-300 method, the system must satisfy the following eligibility criteria:

- The collectors must face within 35 degrees of south and be tilted at a slope of at least 3:12.
- The system must be installed in the exact configuration for which it was rated, e.g. the system must have the same collectors, pumps, controls, storage tank and backup water heater fuel type as the rated condition.
- The system must be installed according to manufacturer's instructions.
- The collectors shall be located in a position that is not shaded by adjacent buildings or trees between 9:00 AM and 3:00 PM (solar time) on December 21.

Test Description

To determine the accuracy of modeling solar systems using the OG 300 method the ACM vendor shall perform the test listed in Table R6-4. The ACM vendor modifies the gas water heating base case and reports the solar savings fraction (SSF) for both the proposed design and the standard design. The Energy Commission reference method shall predict SSF energy within 5% of the candidate ACM.

Table R6-4 – OG-300 Solar Systems Tests

Type	Test	Prototypes	Climates	Optional Capability (Discrete Modification(s))
SS	1	A	3, 9, 12, 14, 16	**Solar System with Electric Backup.** Add a solar system with electric backup that has a SEF of 2.0.
SS	2	A	3, 9, 12, 14, 16	**Solar System with Gas Backup.** Add a solar system with gas backup that has a SEF of 1.0

6.3.4 Water heating Systems for Individual Dwellings or Multi-Family Buildings Based on Collector Tested Using the OG-100 Procedure

Measure Description

The solar thermal systems described in this section have general applicability for water heating applications. They may be used for multi-family or single family water heating systems. Any solar water heating system that uses forced circulation, and collectors rated under the SRCC OG-100 method can use this approach. Situations where this approach might be used are: a single family residences with large hot water demand, solar water heating systems for multi-family buildings, and where a single family system cannot meet the eligibility criteria for OG 300 rated systems. Minimum Reports

A report shall be created that includes the parameters listed in Table R6-5 and Table R6-6.

Prototype

For this series of tests thermal loads and water heating budget shall be based on water heating prototype E (see chapter 5).

Table R6-5 – Prototype Solar System

Parameter	Value
Collector Slope	4:12
Collector Azimuth	180 º (due south)
Collector Area	Four collectors as described below.
Collector Performance (OG 100)	SRCC Certification Number 100-1998-0018 Yint = 0.530, Slope = -0.250 Btu/h-ft²-ºF, A = 32.9 ft²
Storage Tank Size	500 gallons
Pumping	¼ hp pump between collectors and storage tank
Freeze Control	Drain-down

Algorithms and Modeling Assumptions

The Energy Commission reference method is based on the F-Chart procedure, which is available from multiple sources. Modeling inputs and limits for the F-Chart reference method are defined in ACM Appendix RG-2005.

Test Description

To determine the accuracy of modeling solar systems using the SRCC OG100 method, the vendor of the integrated ACM or stand-alone solar application shall perform the test listed in Table R6-6. The integrated ACM or stand-alone solar application shall predict a solar savings fraction (SSF) for the cases in Table R6-6 within plus or minus 3% of the SSF predicted by the Energy Commission reference method.

Table R6-6 – OG 100 Solar System Tests

Type	*Test*	*Prototypes*	*Climates*	*Optional Capability (Discrete Modification(s))*
SS	3	°F	All	**Basecase.** The basecase solar system with the schedule of loads shall be simulated in all climate zones.
SS	4	°F	3, 9, 12, 14, 16	**Collector Orientation.** Vary the orientation of the collectors from due south (the basecase) to 45 degrees east of south.
SS	5	°F	3, 9, 12, 14, 16	**Collector Slope.** Change the collector slope from the 4:12 pitch in the basecase to 12:12.
SS	6	°F	3, 9, 12, 14, 16	**Collector Performance. Substitute the following collector.** SRCC Certification Number 100-1981-0085A Yint = 0.737, Slope = -0.805 Btu/h-ft²-ºF, A = 32.3 ft²
SS	7	°F	3, 9, 12, 14, 16	**Collector Area.** Double the number of collectors
SS	8	°F	3, 9, 12, 14, 16	**Storage Tank Size.** Reduce the storage tank size To 200 gallons.
SS	10	°F	3, 9, 12, 14, 16	**Circulation Pump.** Increase the size of the circulation pump from ¼ hp to ½ hp.
SS	11	°F	3, 9, 12, 14, 16	**Freeze Control.** Change the freeze control from drain-down to glycol.

7. Home Energy Rating Systems (HERS) Required Field Verification and Diagnostic Testing

7.1. California Home Energy Rating Systems

Compliance credit for particular energy efficiency measures, which the Commission specifies, requires field verification and diagnostic testing of as-constructed dwelling units (as defined in Section 7.9) by a certified HERS (Home Energy Rating System) rater. The Commission approves HERS providers, subject to the Commission's HERS regulations, which appear in the California Code of Regulations, Title 20, Division 2, Chapter 4, Article 8, Sections 1670-1675. Approved HERS providers are authorized to certify HERS raters and maintain quality control over field verification and diagnostic testing ratings.

When compliance documentation indicates field verification and diagnostic testing of specific energy efficiency measures as a condition for complying with Title 24, Part 6, an approved HERS provider and certified HERS rater shall be used to conduct the field verification and diagnostic testing. HERS providers and raters shall be considered special inspectors by building departments, and shall demonstrate competence, to the satisfaction of the building official, for the visual inspections and diagnostic testing. The HERS provider and rater shall be independent entities from the builder or subcontractor installer of the energy efficiency improvements being tested and verified, and shall have no financial interest in the installation of the improvements. Third Party Quality Control Programs approved by the Commission may serve the function of HERS raters for field verification purposes as specified in Section 7.6.

The remainder of this chapter describes the:

- Measures that require field verification or testing (including references to test procedures or protocols that shall be followed by installers and HERS raters);
- Required documentation and communication steps;
- Requirements for certification by the installer that the installation complies;
- Required HERS rater verification procedures, and sampling procedures to be used if the builder chooses to do sampling;
- Requirements for Third Party Quality Control Programs that are authorized to serve the function of HERS raters;
- Requirements for sampling when field verification and diagnostic testing is required for additions and alterations; and
- Responsibilities of each of the parties involved in the field verification and diagnostic testing process.

7.2. Measures Required Field Verification and Diagnostic Testing

Table R7-1 describes the measures that require installer certification and HERS rater field verification and diagnostic testing, and identifies the protocol or test procedure in the appendices that shall be used for completing installer and HERS rater diagnostic testing and HERS rater field verification.

Table R7-1 – Summary of Measures Requiring Field Verification and Diagnostic Testing

Measure Title	Description	Protocol or Test Procedure
	Duct Measures	
Duct Sealing	Package D requires that space conditioning ducts be sealed. If sealed and tested ducts are claimed in the proposed design ACM calculation, diagnostic testing is required to verify that leakage is less than the specified criteria.	ACM Appendix RC-2005
Supply Duct Location, Surface Area and R-factor	If compliance credit is claimed for improved supply duct location, surface area and R-value, field verification is required to verify that duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts.[1]	ACM Appendix RC-2005
	Air Conditioner Measures	
Improved Refrigerant Charge	Package D requires in some climate zones that split system air conditioners and heat pumps be diagnostically tested in the field to verify that they have the correct refrigerant charge (see Section 4.7.3). The Proposed Design is modeled with less efficiency if diagnostic testing and field verification is not performed.	ACM Appendix RD-2005
Installation of Thermostatic l Expansion Valve (TXV)	A TXV may be installed as an alternative to refrigerant charge testing. The existence of a TXV has the same calculated benefit as refrigerant charge testing and requires field verification.	ACM Appendix RI-2005
Adequate Air Flow	Air conditioner efficiency requires adequate airflow across the evaporator coil. Compliance credit may be taken when airflow is higher than the criteria specified	ACM Appendix RE-2005
Air Handler Fan Watt Draw	If compliance credit is taken for reductions in fan power, the installed fan power shall be diagnostically tested and verified in the field.	ACM Appendix RE-2005
High Energy Efficiency Ratio (EER)	Compliance credit may be taken for increases in EER by installation of specific air conditioner or heat pump models, but only if the installation of that high EER model is field verified.	ACM Appendix RI-2005
Maximum Cooling Capacity	An additional compliance credit may be taken when the requirements for the combination of adequate air flow, duct sealing and Improved refrigerant charge are met and air conditioners are sized according to the ACM calculations. Field verification is required.	ACM Appendix RF-2005
	Building Envelope Measures	
Building Envelope Sealing	The default building envelope specific leakage area (SLA) is specified in Section 4.5.1. Compliance credit may be taken for improved building envelope sealing, but only if lower SLA values are field verified through diagnostic testing.	ASTM E779-03
High Quality Insulation Installation	ACMs recognize Standard and improved envelope construction. Compliance credit for improved envelope construction requires field verification.	ACM Appendix RH-2005

1. Note: Compliance credit for increased duct insulation R-value (not buried ducts) may be taken without field verification if the R-value is the same throughout the building, and for supply ducts located in crawlspaces and garages where all supply registers are either in the floor or within 2 feet of the floor. These two credits may be taken subject only to building department inspection.

2. Note: The requirement for verification of a high EER does not apply to equipment rated only with an EER.

All features that require verification and/or testing shall be listed in the *Field Verification and Diagnostic Testing* section of on the *Certificate of Compliance* (CF-1R). The listing shall include “eligibility and installation criteria” for such features. Field verified and diagnostically tested features shall be described in the *Compliance Supplement*. Installers shall certify that the requirements for compliance have been met on the *Installation Certificate* (CF-6R). Field Verification and diagnostic testing shall be performed by a HERS rater and documented on the *Certificate of Field Verification and Diagnostic Testing* (CF-6R).

7.3. Summary of Documentation and Communication

The documentation and communication process for measures that require field verification and diagnostic testing is summarized below. The subsequent sections of this chapter contain additional information.

- The documentation author shall complete the compliance documents, including the CF-1R. A CF-1R shall be prepared for each dwelling unit. For multi-family buildings a single CF-1R is typically prepared for a whole building, but separate compliance documentation shall be required for dwelling units that have measures requiring field verification and diagnostic testing.
- The documentation author shall provide a signed Certificate of Compliance (CF-1R) to the builder, which indicates that any HERS diagnostic testing and field verification measure is required for compliance. The builder shall make arrangements for the services of a certified HERS rater prior to installation of the measures, so that once the installation is complete the HERS rater has ample time to complete the field verification and diagnostic testing without delaying final approval of occupancy by the building department.
- The builder or subcontractor installs the measure(s) that require field verification and diagnostic testing. The builder or installer completes diagnostic testing and the procedures specified in Section 7.4. When the installation is complete, the builder or subcontractor completes the CF-6R (Installation Certificate), keeping it at the building site for review by the building department. A copy of the CF-6R is also provided to the HERS rater.
- The HERS rater shall complete the field verification and diagnostic testing as specified in Section 7.5, and provides signed CF-4Rs, Certificate of Field Verification and Diagnostic Testing, to the HERS provider, builder and building department. The building department shall not approve a dwelling unit for occupancy until the building department has received a CF-4R that has been signed by the certified HERS rater.

7.4 Installer Requirements for Installation Certification (CF-6R)

Installation certificates (CF-6R) are required for each and every dwelling unit. When the installation of measures that require field verification and diagnostic testing is complete, the builder or the builder's subcontractor shall complete diagnostic testing and the procedures specified in this section. When the installation is complete, the builder or the builder's subcontractor shall complete the CF-6R (Installation Certificate), and keep it at the building site for review by the building department. The builder also shall provide a copy of the Installation Certificate to the HERS rater for any measures requiring field verification and diagnostic testing.

7.4.1 Measures Requiring Diagnostic Testing and Field Verification

When compliance includes duct sealing, improved air conditioner refrigerant charge and airflow across the evaporator coil, reduced air conditioner fan power or building envelope sealing, builder employees or subcontractors shall:

- complete diagnostic testing, and
- certify on the CF-6R the diagnostic test results and that the work meets the requirements for compliance credit.

For refrigerant charge and airflow measurement when the outside temperature is below 55°F, the installer shall follow the alternate charge and airflow measurement procedure described in Appendix RD, Section RD3. Builder employees or subcontractors using these procedures shall certify on the CF-6R that they used these procedures, the diagnostic results, that the work meets the requirements for compliance credit, and that they will return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

For duct sealing diagnostic testing completed at the rough-in stage of construction, builder employees or subcontractors shall:

- at rough-in, complete the fan pressurization test and certify on the CF-6R the diagnostic results,
- after installation of the interior finishing wall, complete the installer visual inspection at final construction stage (See ACM RC-2005), and
- certify on the CF-6R the diagnostic results and that the work meets the requirements for compliance credit.

7.4.2 Measures Requiring Field Verification

When compliance includes supply duct location, surface area and R-value improvements, installation of an air conditioner thermostatic expansion valve, high air conditioner EER, and high quality building envelope construction builder employees or subcontractors shall:

- record the feature on the CF-6R,
- record on the CF-6R field measurements required to field verify the measure, and
- certify on the CF-6R that the work meets the requirements for compliance credit.

7.5 Verification and Sampling Procedures

At the builder's option HERS field verification and diagnostic testing shall be completed either for each dwelling unit or for a sample of dwelling units in which the measure requiring field verification and diagnostic testing is installed. Note that if multiple measures requiring field verification and diagnostic testing are installed in dwelling units, sample testing does not have to be completed for all of the measures in the same dwelling unit. Dwelling units in the sample shall be in the same subdivision or multifamily housing development. Field verification and diagnostic testing for compliance credit for duct sealing shall use the diagnostic duct leakage from fan pressurization of ducts in Section RC3.1, ACM RC-2005. Field verification and diagnostic testing for compliance credit for refrigerant charge and airflow measurement shall use the standard charge and airflow measurement procedure specified in ACM RD-2005. Field verification and diagnostic testing shall not use the alternate charge and airflow measurement procedure. Field verification and diagnostic testing shall be scheduled and completed when the outside temperature is above 55°F.

The builder shall provide the HERS rater a copy of the CF-6R containing the installation certifications required in Section 7.4. Prior to completing field verification and diagnostic testing, the HERS rater shall first verify that the installation certifications have been completed.

If the builder chooses the sampling option, the procedures described in this section shall be followed. Sampling procedures described in this section shall be included in the *Residential Manual*.

7.5.1 Initial Field Verification and Testing

The HERS rater shall diagnostically test and field verify the first dwelling unit of each model. To be considered the same model, dwelling units shall be in the same subdivision or multifamily housing development and have the same energy designs and features, including the same floor area and volume, for each dwelling unit, as shown on the CF-1R. For multi-family buildings, variations in exterior surface areas caused by location of dwelling units within the building shall not cause dwelling units to be considered a different model. This initial testing allows the builder to identify and correct any potential construction flaws or practices in the build out of each model. If field verification and diagnostic testing determine that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* (CF-4R) to the builder the HERS provider, and the building department.

7.5.2 Sample Field Verification and Testing

After the initial testing is completed, the builder shall identify a group of up to seven dwelling units from which a sample will be selected for testing, and notify the HERS provider. If multiple measures requiring field verification and diagnostic testing are installed, each dwelling unit in the group shall have the same measures requiring field verification and diagnostic testing as the other dwelling units in the group. If some dwelling units have installed a different set of measures requiring field verification and diagnostic testing, these dwelling units shall be in a separate group.

The builder shall identify the group of dwelling units by location of County, City and either the street address or the subdivision and lot number, or the multifamily housing project name and shall identify the names and license numbers of subcontractors responsible for installations requiring diagnostic testing or field verification. The builder may remove dwelling units from the group by notifying the HERS provider. Removed dwelling units which are constructed shall either be field verified and diagnostically tested individually or shall be included in a subsequent group for sampling.

The HERS rater shall select a minimum of one dwelling unit out of the group for diagnostic testing and field verification. When several dwelling units are ready for testing at the same time, the HERS rater shall randomly select the dwelling units to be tested. The HERS rater shall diagnostically test and field verify the dwelling units selected by the HERS rater.

If field verification and diagnostic testing determines that the requirements for compliance are met, the HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder, the HERS provider, and the building department. The *Certificate of Field Verification and Diagnostic Testing* shall report the successful diagnostic testing results and conclusions regarding compliance for the tested dwelling unit.

The HERS rater shall also provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder and the HERS provider for up to six additional dwelling units in the group. The *Certificate* shall not be provided for dwelling units in which the feature requiring field verification and diagnostic testing has not been installed, sealed or completed.

Whenever the builder changes subcontractors who are responsible for the feature that is being diagnostically field verified and tested, the builder shall notify the HERS rater of any subcontractors who have changed, and terminate sampling for the identified group. All dwelling units using *HERS Required Verification* features for compliance that were installed by previous subcontractors or were subject to verification and testing under the supervision of a previous HERS provider, for which the builder does not have a completed *Certificate of Field Verification and Diagnostic Testing*, shall either be individually tested or included in a separate group for sampling. Dwelling units with installations completed by new subcontractors shall either be individually tested or shall be included in a new sampling group following a new *Initial Field Verification and Testing*.

The HERS rater shall not notify the builder when sample testing will occur prior to the completion of the work that is to be tested. After the HERS rater notifies the builder when testing will occur, the builder shall not do additional work on the features being tested.

7.5.3 Re-sampling, Full Testing and Corrective Action

When a failure is encountered during sample testing, the HERS rater shall conduct re-sampling to assess whether that failure is unique or the rest of the dwelling units are likely to have similar failings. The HERS rater shall select for re-sampling one of the up to six untested dwelling units in the group.

If testing in dwelling units in the re-sample confirms that the requirements for compliance credit are met, then the dwelling unit with the failure shall not be considered an indication of failure in the other dwelling units in the group. The HERS rater shall provide a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder, the HERS provider, and the building department for up to six additional dwelling units in the group, including the dwelling unit in the re-sample. The builder shall take corrective action for the dwelling unit with the failure, and then the HERS rater shall retest to verify compliance and issue a signed and dated *Certificate of Field Verification and Diagnostic Testing* to the builder.

If field verification and testing in the re-sample results in a second failure, the builder shall take corrective action in all unoccupied dwelling units in the group that have not been tested. In cases where corrective action would require destruction of building components, the builder may choose to reanalyze compliance and choose different measures that will achieve compliance. In this case a new Certificate of Compliance shall be completed and submitted to the HERS provider, HERS rater and building department. When a builder chooses to take corrective action, the HERS rater shall conduct field verification and diagnostic testing in each of these dwelling units to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider, the builder, and the building department.

Builders shall offer at no charge to building owners (for a definition of “building owner” and of other terms used see Section 7.9) in occupied dwelling units in the group to complete field verification and testing and corrective action if necessary. Builders shall report to the HERS provider the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective. The HERS provider shall verify that the builder has made this offer. If a building owner in an occupied dwelling unit declines this offer, field verification, testing and corrective action will not be required for that dwelling unit and the dwelling unit will no longer be considered a part of the group. If a building owner accepts this offer, the builder shall take corrective action. The HERS rater shall then conduct field verification and diagnostic testing to verify that problems have been corrected and that the requirements for compliance have been met, and shall report to the HERS provider, builder, and the building department.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective action, offers to building owners for testing and corrective action and building owner declines of such offers) to bring into compliance dwelling units for which full testing has been required. If corrective action requires work not specifically exempted by the CMC or the CBC, the builder shall obtain a permit from the building department prior to commencement of any of the work.

If additional dwelling units in the group are completed during the time required to correct, field verify and test the previously completed dwelling units in the group, the rater shall individually field verify and diagnostically test those additional dwelling units to confirm that the requirements for compliance credit are met.

Corrections shall not be made to a sampled or re-sampled dwelling unit to avoid a failure. If corrections are made to a sampled or re-sampled dwelling unit to avoid failure, corrections, field verification and testing shall be performed on 100% of the dwelling units in the group.

7.6 Third Party Quality Control Programs

The Commission may approve Third Party Quality Control Programs that serve the function of HERS raters for field verification purposes. Third Party Quality Control Programs shall provide training to installers regarding compliance requirements for measures for which diagnostic testing and field verification is required. Third Party Quality Control Programs shall collect data from participating installers for each installation completed for compliance credit, complete data checking analysis to evaluate the validity and accuracy of the data to independently determine whether compliance has been achieved, provide direction to the installer to retest and correct problems when data checking determines that compliance has not been achieved, require resubmission of data when retesting and correction is directed, and maintain a database of all data submitted by installers in a format that is acceptable to the Commission and available to the Commission upon request. The data that is collected by the Third Party Quality Control Program shall be more detailed than the data required for showing compliance with the Standards, shall provide an independent check on the validity and accuracy of the installer’s claim that compliance has been achieved, and shall not be alterable by the installer to indicate that compliance has been achieved when in fact compliance has not been achieved.

The Third Party Quality Control Program shall also obtain the services of a HERS rater to conduct independent field verifications, completing all of the responsibilities of a HERS rater as specified in this Chapter with the exception that sampling shall be completed for a group of up to thirty dwelling units with a minimum sample of one out of every thirty sequentially completed dwelling units from the group. The HERS rater shall be an independent entity from the Third Party Quality Control Program. Re-sampling, Full Testing and Corrective Action shall be completed as specified in section 7.5.3 with the exception that re-sampling shall be completed for a minimum of one out of every thirty dwelling units from the group.

The Third Party Quality Control Program shall meet all of the requirements of a HERS rater specified in the Commission's HERS Program regulations (California Code of Regulations, Title 20, Division 2, Chapter 4, Article 8, Sections 1670 -1675), including the requirement to be an independent entity from the builder and the HERS rater that provides independent field verifications, subcontractor installer as specified by section 1673(i). A Third Party Quality Control Program may have business relationships with installers participating in the Program to advocate or promote the Program and an installer's participation in the Program, and to advocate or promote products that the Third Party Quality Control Program sells to installers as part of the Program.

Prior to approval by the Commission, the Third Party Quality Control Program shall provide a detailed explanation to the Commission of 1) the data that is to be collected from the installers, 2) the data checking process that will be used to evaluate the validity and accuracy of the data, 3) the justification for why this data checking process will provide strong assurance that the installation actually complies, and 4) the format for the database that will be maintained and provided to the Commission upon request. The Third Party Quality Control Program may apply for a confidential designation of this information as specified in the Commission's Administrative Regulations (California Code of Regulations, Title 20, Division 2, Chapter 7, Article 2, Section 2505). The Third Party Quality Control Program shall also provide a detailed explanation of the training that will be provided to installers, and the procedures that it will follow to complete independent field verifications.

The Third Party Quality Control Program shall be considered for approval as part of the rating system of a HERS Provider, which is certified as specified in the Commission's HERS Program regulations, Section 1674. A Third Party Quality Control Program can be added to the rating system through the recertification of a certified HERS Provider as specified by Section 1674(d).

7.7 Sampling for Additions or Alterations

When compliance for an addition or alteration requires diagnostic testing and field verification, the building owner may choose for the testing and field verification to be completed for the dwelling unit alone or as part of a sample of dwelling units for which the same installing company has completed work that requires testing and field verification for compliance. The building owner or agent of the building owner shall complete the applicable portions of a Certificate of Compliance (CF-1R). The HERS provider shall define the group for sampling purposes as all dwelling units where the building permit applicant has chosen to have testing and field verification completed as part of a sample for the same installing company. The group shall be no larger than seven. The installing company may request a smaller group for sampling. Whenever the HERS rater for the group is changed, a new group will be established. Initial Field Verification and Testing shall be completed for the first dwelling unit in each group. Re-sampling, Full Testing and Corrective Action shall be completed if necessary as specified by section 7.5.3.

Field verification may be completed by an approved Third Party Quality Control Program as specified in section 7.6. The group for sampling purposes shall be no larger than thirty when a Third Party Quality Control Program is used. The Third Party Quality Control Program may define the group instead of the Provider. When a Third Party Quality Control Program is used, the CF-6R shall document that data checking has indicated that the dwelling unit complies. The building official may approve compliance based on the CF-6R on the condition that if sampling indicates that re-sampling, full testing and corrective action is necessary, such work shall be completed.

7.8 Summary of Responsibilities

This section summarizes responsibilities described previously in this chapter and organizes them by the responsible party.

7.8.1 Builder

The builder shall make arrangements for the services of a certified HERS rater prior to installation of the measures, so that once the installation is complete the HERS rater has ample time to complete the field verification and diagnostic testing without delaying final approval of occupancy by the building department.

Builder employees or subcontractors responsible for completing either diagnostic testing, visual inspection or verification as specified in Section 7.4 shall certify the diagnostic testing results and that the work meets the requirements for compliance credit on the CF-6R.

The builder shall provide the HERS rater with the identifying location of the group of dwelling units to be included in the sample for field verification and diagnostic testing. The builder shall provide the HERS provider a copy of the CF-6R signed by the builder employees or sub-contractors certifying that diagnostic testing and installation meet the requirements for compliance credit.

The builder shall provide a *Certificate of Field Verification and Diagnostic Testing* (CF-4R) signed and dated by the HERS rater to the building official in conjunction with requests for final inspection for each dwelling unit.

When re-sampling reveals a failure, builders shall offer, at no charge to building owners in occupied dwelling units in the group, to complete field verification, testing and corrective action if necessary. Building owners may decline to have field verification and testing and corrective action completed. Builders shall report the identifying location of any dwelling unit in which the building owner declines field verification and testing and corrective action to the HERS provider. Builders shall take corrective action as required in all unoccupied dwelling units in the group and in occupied dwelling units in the group where building owners have accepted field verification, testing and corrective action.

7.8.2 HERS Provider and Rater

The HERS provider shall maintain a list of the dwelling units in the group from which sampling is drawn, the dwelling units selected for sampling, the dwelling units sampled and the results of the sampling, the dwelling units selected for re-sampling, the dwelling units that have been tested and verified as a result of re-sampling, the corrective action taken, and copies of all *Certificates of Field Verification and Diagnostic Testing* for a period of five years.

The HERS rater providing the diagnostic testing and verification shall sign and date a *Certificate of Field Verification and Diagnostic Testing* certifying that he/she has verified that the requirements for compliance credit have been met. *Certificates of Field Verification and Diagnostic Testing* shall be provided for the tested dwelling unit and each of up to six other dwelling units from the group for which compliance is verified based on the results of the sample. The HERS rater shall provide this certificate to the builder, the HERS provider, and the building department.

The HERS rater shall provide a separate *Certificate of Field Verification and Diagnostic Testing* for each dwelling unit the rater determines has met the diagnostic requirements for compliance. The HERS rater shall identify on the *Certificate of Field Verification and Diagnostic Testing* if the dwelling unit has been tested or if it was an untested dwelling unit approved as part of sample testing. The HERS rater shall not sign a *Certificate of Field Verification and Diagnostic Testing* for a dwelling unit that does not have a CF-6R signed by the installer as required in Section 7.4.

If field verification and testing on a sampled dwelling unit identifies a failure to meet the requirements for compliance credit, the HERS rater shall report to the HERS provider, the builder, and the building department that re-sampling will be required.

If re-sampling identifies another failure, the HERS rater shall report to the HERS provider, the builder, and the building department that corrective action and diagnostic testing and field verification will be required for all the untested dwelling units in the group. This report shall specify the identifying location of all dwelling units that shall be fully tested and corrected.

The HERS provider shall also report to the builder once diagnostic testing and field verification has shown that the failures have been corrected in all of the dwelling units except those for which the building owner has declined field verification, testing and corrective action.

When individual dwelling unit testing and verification confirms that the requirements for compliance have been met, the HERS rater shall provide a *Certificate of Field Verification and Diagnostic Testing* for each dwelling unit in the group.

The HERS provider shall file a report with the building department explaining all action taken (including field verification, testing, corrective actions, offers to building owners for testing and corrective action, and building owner declines of such offers) to bring into compliance dwelling units for which full testing has been required.

7.8.3 Third Party Quality Control Program

An approved Third Party Quality Control Program shall:

- Provide training to installers regarding compliance requirements for measures for which diagnostic testing and field verification is required,
- Collect data from participating installers for each installation completed for compliance credit,
- Complete data checking analysis to evaluate the validity and accuracy of the data to independently determine whether compliance has been achieved,
- Provide direction to the installer to retest and correct problems when data checking determines that compliance has not been achieved,
- Require resubmission of data when retesting and correction is directed, and
- Maintain a database of all data submitted in a format that is acceptable to the Commission and available to the Commission upon request.

The Third Party Quality Control Program shall obtain the services of an independent HERS rater to conduct independent field verifications, completing all of the responsibilities of a HERS rater as specified in this Chapter with the exception that sampling shall be completed for a group of up to thirty dwelling units and sampling and re-sampling shall be completed for a minimum of one out of every thirty sequentially completed dwelling units from the group.

7.8.4 Building Department

The building department at its discretion may require independent testing and field verification to be scheduled so that it can be completed in conjunction with the building department's required inspections, and/or observe the diagnostic testing and field verification performed by builder employees or subcontractors and the certified HERS rater in conjunction with the building department's required inspections to corroborate the results documented in installer certifications, and in the *Certificate of Field Verification and Diagnostic Testing*.

For dwelling units that have used a compliance alternative that requires field verification and diagnostic testing, the building department shall not approve a dwelling unit for occupancy until the building department has received a *Certificate of Field Verification and Diagnostic Testing* that has been signed and dated by the HERS rater.

If necessary to avoid delay of approval of dwelling units completed when outside temperatures are below 55°F, building departments may approve compliance credit for refrigerant charge and airflow measurement when installers have used the alternate charging and airflow measurement procedure described in ACM Appendix RD-2005, Section RD3. This approval will be on the condition that installers provide a signed agreement to the builder with a copy to the building department to return to correct refrigerant charge and airflow if the HERS rater determines at a later time when the outside temperature is above 55°F that correction is necessary.

7.9 Definitions of Terms Used In This Chapter

The following definitions apply to the procedures described in this document.

Building Owner means the owner of the dwelling unit.

Builder means the general contractor responsible for construction.

Building Department means the city, county or state agency responsible for approving the plans, issuing a building permit and approving occupancy of the dwelling unit.

Dwelling Unit means the building for single-family residences or each dwelling unit within a multifamily building project.

HERS Provider means an organization that the Commission has approved to administer a home energy rating system program, certify raters and maintain quality control over field verification and diagnostic testing required for compliance with the Energy Efficiency Standards.

HERS Rater means a person certified by a Commission approved HERS Provider to perform the field verification and diagnostic testing required for demonstrating compliance with the standards.

Independent Entity means having no financial interest in, and not advocating or recommending the use of any product or service as a means of gaining increased business with, firms or persons specified in Section 1673(i) of the California Home Energy Rating System Program regulations (California Code of Regulations, Title 20, Division 2, Chapter 4, Article 8). **Financial Interest** means an ownership interest, debt agreement, or employer/employee relationship. Financial interest does not include ownership of less than 5% of the outstanding equity securities of a publicly traded corporation.

NOTE: The definitions of "independent entity" and "financial interest," together with Section 1673(i), prohibit conflicts of interest between providers and raters, or between providers/raters and builders/subcontractors.

Documentation Author means the person responsible for completing the compliance documentation that demonstrates whether a building complies with the standards. Compliance documentation requirements are defined in the Residential Manual.

Model means a floor plan and house design that is repeated throughout a subdivision or within a multi-family building. To be considered the same model, dwelling units shall be in the same subdivision or multi-family housing development and have the same energy designs and features, including the same floor area and volume, for each dwelling unit, as shown on the CF-1R. For multi-family buildings, variations in exterior surface areas caused by location within the building shall not cause dwelling units to be considered a different model.

Certificate of Field Verification and Diagnostic Testing (CF-4R) means a document with information required by the Commission that is prepared by the HERS rater to certify that measures requiring field verification and diagnostic testing comply with the requirements.

Certificate of Compliance (CF-1R) means a document with information required by the Commission that is prepared by the Documentation Author that indicates whether the building includes measures that require field verification and diagnostic testing.

Installation Certificate (CF-6R) means a document with information required by the Commission that is prepared by the builder or installer verifying that the measure was installed to meet the requirements of the standards.

8. Compliance Supplement

Each ACM vendor is required to publish a Compliance Supplement to the normal program users manual. The Compliance Supplement serves two major purposes. First, it helps building permit applicants to use the ACM correctly and to prepare complete documentation of their analyses. Second, it helps building officials to check permit applications for compliance with the low-rise residential Building Energy Efficiency Standards. As a result, it helps to assure that both the performance standards and the ACM are used properly.

The Compliance Supplement shall describe the specific procedures for using the ACM for compliance with the Building Energy Efficiency Standards. The supplement shall provide instructions for preparing the building input, using the correct fixed and restricted inputs, and for using each of the optional capabilities for which the ACM is approved. Also included are procedures for generating the standard reports and documenting the analysis. A sample of a properly documented building analysis shall be included.

All Compliance Supplements shall be written in a clear and concise manner and with a common organization and format. Variations in format may be approved by the Energy Commission, however, to allow for the differences between ACMs. This will assure consistency between the compliance supplements of different ACMs, simplifying the enforcement task of building officials. Also, vendors of approved ACMs are required to make copies of their compliance supplement available to all building departments in California.

The following sections describe the information that shall be included in all compliance supplements. It also presents the required organization for that information.

8.1 Energy Commission Approval

This section includes a copy of the official Energy Commission notice of approval of the ACM. The notice may include restrictions or limitations on the use of the ACM. It will also include the date of approval, and may include an expiration date for approval as well. The notice will indicate which optional capabilities the ACM is approved for and other restrictions on its use for compliance. The Energy Commission will provide this notice upon completion of evaluation of the ACM application.

8.2 Program Capabilities

This section discusses the program capabilities, with supporting written material explaining, as necessary, how the ACM treats each one. Reference may be made to non-compliance sections of the ACM Users Manual for more complete descriptions, if they exist.

8.3 Standard Input/Output Report

This section explains how to use the program to prepare the standard input/output reports.

8.4 Fixed and Restricted Inputs

Approved ACMs shall automatically use the standard fixed and restricted inputs for the standard design run. It shall also default to the standard assumptions for the proposed design run. When the alternative fixed and restricted inputs are used for the proposed design run, the ACM shall report this in the *Special Features and Modeling Assumptions* sections of the standard reports.

This section of the Compliance Supplement explains the fixed and restricted inputs and how they are invoked in the ACM. This is especially important if the ACM offers the possibility of non-compliance runs which can deviate from the fixed and restricted inputs.

8.5 Preparing Basic Input

This section covers the basic use of the ACM for compliance. Optional capabilities are described in greater detail. Reference may be made to the users manual, but this section should include a complete summary of all inputs and/or commands necessary for compliance.

8.6 Optional Capabilities

This section explains the procedures for using each of the optional capabilities of the ACM. It is a parallel section to the basic inputs section above. The section for each optional capability should explain how to prepare inputs, how to document assumptions, and what the limitations are of each analysis capability.

8.7 Special Features and Modeling Assumptions

This section explains the use of the Special Features and Modeling Assumptions listing to highlight the importance of verifying the special features and the aspects of those features that were modeled to achieve compliance.

8.8 Field Verification

This section explains the use of the Field Verification and Diagnostic Testing listing to highlight the special features that require diagnostic testing by a certified home energy rater under the supervision of an Energy Commission approved HERS provider to assure proper installation and verification. This section may rely on the information provided in Chapter 7, other sections of this manual, or may refer to other Commission documents.

8.9 Checklist for Compliance Submittal

This section should contain a concise checklist of all items that shall be included in a compliance submittal to a building official using the ACM.

8.10 Sample Compliance Documentation

This section should include a complete set of compliance documentation for a sample building. The building need not be overly complex, nor need it include every program capability. The example should, however, include all documentation and standard reports that would normally be submitted. This example will serve as a model to ACM users and building officials of what a proper compliance submittal should look like.

8.11 Compliance Statement

The following statement shall appear within the first several pages of the Supplement:

> [ACM Name] may be used to show compliance with California's Residential Building Energy Efficiency Standards.

8.12 Related Publications

The Compliance Supplement should refer users to the following related Energy Commission publications and where to obtain them:

- *2005 Building Energy Efficiency Standards* (P400-03-001F)
- *2005 Residential Manual* (publication number unknown at time of printing)

Both publications are available from:

California Energy Commission
Publications Unit
1516 Ninth Street
Sacramento CA 95814
(916) 654-5200

9. Vendor Requirements Availability to the Energy Commission

All ACM vendors are required to submit at least one version of the ACM to the California Energy Commission. An updated copy or access to the approved version of the ACM shall be kept by the Energy Commission to maintain approval for compliance usage of the ACM. The Energy Commission agrees not to duplicate the ACM except for the purpose of analyzing it, for verifying building compliance with the ACM, or to verify that only approved versions of the ACM are used for compliance.

9.1 Building Department Support

ACM vendors shall provide a copy of the ACM Compliance Supplement to all local building enforcement agencies who request one in writing.

9.2 User Support

It is expected that ACM vendors will offer support to their users with regard to the use of the ACM for compliance purposes. Vendors may charge a fee for user support.

9.3 ACM Vendor Demonstration

The Energy Commission may request ACM vendors to physically demonstrate their program's capabilities. One or more demonstrations may be requested before approval is granted.

Appendices Table of Contents

ACM RESIDENTIAL MANUAL APPENDIX RA-2005

Appendix RA – Certification of Alternative Calculation Method

Energy Efficiency Standards for Residential Buildings, Sections 150 to 152

I, _______________________________________ (name), certify that this alternative calculation method (ACM), ______________________________________ (name of ACM), version number ___________, dated ___________________, developed by, _____________________________ (personnel or company), ____________________________ (address) _____________________________ (city, state) ________ (zip), passes all of the ACM tests and gives results that are reliable and accurate when used for calculating custom budgets and annual energy use estimates to comply with CEC (California Energy Commission) regulations, subject to the fixed and restricted assumptions specified in the *Alternative Calculation Method (ACM) Approval Manual for the 2005 Energy Efficiency Standards for Residential Buildings*, and the fixed and restricted inputs specified in the manuals describing the use of this method (Users Manual and Compliance Supplement thereto). I certify that the calculation of energy use in buildings, following the instructions in the manuals, and using accurate and complete plans and specifications for a building will achieve reliable and accurate energy analysis results with this ACM. Moreover, the calculations are verifiable when modeling the same building and accurately applying the fixed and restricted assumptions and inputs mentioned above. I further certify that all variables used by the program that are not subject to ready verification in the plans and specifications or that are subject to occupant use are either fixed, carefully restricted, or defaulted in this ACM.

I also certify that the inputs, default values, and assumptions specified for compliance runs in the manuals, and used in the accompanying application for the CEC residential ACM approval, are consistent with the inputs, default values, and assumptions specified by the CEC in the *Alternative Calculation Method (ACM) Approval Manual for the 2005 Energy Efficiency Standards for Residential Buildings* for use when generating standard design budgets and annual energy use estimates. I also certify that all specific inputs, variables, and assumptions needed to achieve the accuracy required to pass the capability tests in the *ACM Approval Manual* are either not subject to user variation, are defaulted to the values used for compliance, or are clearly specified as restricted or required inputs in the manuals for the ACM. In addition, the manuals clearly indicates that an easily verified list of the actual values of any such variables used for performance approach compliance which are subject to programmatic or user variation are to be included with the compliance documentation supplied by a building permit applicant to the enforcement agency. In summary, I also certify that the results of this alternative calculation method as specified in the manuals for the ACM in conjunction with an accurate and adequate set of plans and specifications for a building are not subject to significant variation by the manipulation of unrestricted user specified inputs that are difficult or impossible to verify.

In certifying the reliability and accuracy of this ACM, I certify that the results of this ACM's calculations, algorithms and assumptions are open to inspection by any individual or State entity, that this ACM may be challenged for its validity and accuracy as specified by the ACM Approval Manual, and that if challenged, I will prepare an adequate response or face possible withdrawal of ACM approval.

This certification is based upon the tests and requirements specified in the *Alternative Calculation Method (ACM) Approval Manual for the 2005 Energy Efficiency Standards for Residential Buildings,* and upon personal knowledge and experience with the use of this alternative calculation method.

Signed Date Title

RA.1 Space Conditioning Tests (SC)

Complete the unshaded areas of the following forms. An electronic version of this document is available from the CEC.

Test SC00 – Basecase Simulations

Enter the TDV energy for the standard design and the proposed design – values should match.

Test Label	TDV Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SC00A01			
SC00A02			
SC00A03			
SC00A04			
SC00A05			
SC00A06			
SC00A07			
SC00A08			
SC00A09			
SC00A10			
SC00A11			
SC00A12			
SC00A13			
SC00A14			
SC00A15			
SC00A16			
SC00B01			
SC00B02			
SC00B03			
SC00B04			
SC00B05			
SC00B06			
SC00B07			
SC00B08			
SC00B09			
SC00B10			
SC00B11			
SC00B12			
SC00B13			
SC00B14			
SC00B15			
SC00B16			

Test SC01 – SEER vs. AFUE

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC01A03						
SC01A09						
SC01A12						
SC01A14						
SC01A16						

Test SC02 – Ceiling U-factor vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC02A03						
SC02A09						
SC02A12						
SC02A14						
SC02A16						

Test SC03 – Wall U-factor vs. West Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		West Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC03A03						
SC03A09						
SC03A12						
SC03A14						
SC03A16						

Test SC04 – Slab F-factor vs. North Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC04A12						
SC04A14						
SC04A16						

Test SC05 – Fenestration Type vs. North Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC05A03						
SC05A09						
SC05A12						
SC05A14						
SC05A16						

Test SC06 – Fenestration Type vs. AFUE

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC06A03						
SC06A09						
SC06A12						
SC06A14						
SC06A16						

Test SC07 – Exposed Thermal Mass vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC07A12						
SC07A14						
SC07A16						

Test SC08 – Exposed Thermal Mass vs. West Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		West Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC08A03						
SC08A09						
SC08A12						
SC08A14						
SC08A16						

Test SC09 – Exposed Thermal Mass vs. North Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		North Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC09A03						
SC09A09						
SC09A12						
SC09A14						
SC09A16						

Test SC10 – Exposed Thermal Mass vs. East Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		East Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC10A03						
SC10A09						
SC10A12						
SC10A14						
SC10A16						

Test SC11 – South Overhangs vs. South Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		South Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC11A03						
SC11A09						
SC11A12						
SC11A14						
SC11A16						

Test SC12 – Building Envelope Sealing vs. Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC12A03						
SC12A09						
SC12A12						
SC12A14						
SC12A16						

Test SC13 – Building Envelope Sealing and Mechanical Ventilation vs. Glass Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Glass Solution (ft²)		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC13A03						
SC13A09						
SC13A12						
SC13A14						
SC13A16						

Test SC14 – Construction Quality vs. AFUE

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC14A03						
SC14A09						
SC14A12						
SC14A14						
SC14A16						

Test SC15 – Cool Roofs/Radiant Barrier vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC15A09						
SC15A12						
SC15A14						

Test SC16 – Natural Ventilation vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC16A09						
SC16A12						
SC16A14						

Test SC17 – Duct Leakage vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC17A03						
SC17A09						
SC17A12						
SC17A14						
SC17A16						

Test SC18 – Duct Surface Area vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC18A03						
SC18A09						
SC18A12						
SC18A14						
SC18A16						

Test SC19 – Duct Location vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC19B09						
SC19B12						
SC19B14						

Test SC20 – Duct Insulation vs. SEER

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC20A09						
SC20A12						
SC20A14						

Test SC21 – Energy Efficiency Ratio vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC21A09						
SC21A12						
SC21A14						

Test SC22 – TXV/Charge Testing vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC22A09						
SC22A12						
SC22A14						

Test SC23 – Airflow Across Evaporator Coil vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC23A09						
SC23A12						
SC23A14						

Test SC24 – Air Conditioner Fan Power vs. SHGC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SHGC Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC24A09						
SC24A12						
SC24A14						

Test SC25 – Electric Heat vs. Fenestration U-Factor

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC25A03						
SC25A09						
SC25A12						
SC25A14						
SC25A16						

Test SC26 – Side Fins

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		SEER Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
SC26A09						
SC26A12						
SC26A14						

RA.2 Standard Design Tests (SD)

Test SD01 – Single-Family Slab-on-Grade

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD01C01					
SD01C02					
SD01C03					
SD01C04					
SD01C05					
SD01C06					
SD01C07					
SD01C08					
SD01C09					
SD01C10					
SD01C11					
SD01C12					
SD01C13					
SD01C14					
SD01C15					
SD01C16					

Test SD02 – Single-Family Raised Floor

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD02D01					
SD02D02					
SD02D03					
SD02D04					
SD02D05					
SD02D06					
SD02D07					
SD02D08					
SD02D09					
SD02D10					
SD02D11					
SD02D12					
SD02D13					
SD02D14					
SD02D15					
SD02D16					

Test SD03 – Multi-Family Slab on Grade

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD03E01					
SD03E02					
SD03E03					
SD03E04					
SD03E05					
SD03E06					
SD03E07					
SD03E08					
SD03E09					
SD03E10					
SD03E11					
SD03E12					
SD03E13					
SD03E14					
SD03E15					
SD03E16					

Test SD04 – Neutral Variable Test: Window Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD04A03					
SD04A09					
SD04A12					
SD04A14					
SD04A16					

Test SD05 – Neutral Variable Test: Wall Area

Label	Space Conditioning TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
SD05A03					
SD05A09					
SD05A12					
SD05A14					
SD05A16					

RA.3 Additions and Alterations Tests

Test AA01 – Baseline Simulations

Label	TDV Energy (kBtu/ft²/y)		ACM Filenames
	Standard Design	Proposed Design	
AA01E03			
AA01E09			
AA01E12			
AA01E14			
AA01E16			

Test AA02 – Increase Glass

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
AA02E03						
AA02E09						
AA02E12						
AA02E14						
AA02E16						

Test AA03 – New HVAC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
AA02E03						
AA02E09						
AA02E12						
AA02E14						

AA02E16						

Test EA01 – Baseline

Label	TDV Energy (kBtu/ft²/y)		ACM Filenames
	Standard Design	Proposed Design	
EA01E03			
EA01E09			
EA01E12			
EA01E14			
EA01E16			

Test EA02 – Increase Glass

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
EA02E03						
EA02E09						
EA02E12						
EA02E14						
EA02E16						

Test EA03 – New HVAC

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
EA02E03						
EA02E09						
EA02E12						
EA02E14						
EA02E16						

RA.4 Water Heating Tests

Complete the unshaded areas of the following forms. An electronic version of this document is available from the CEC.

Test WH00 – Basecase Simulations

Enter the TDV water heating energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
WH00C01			
WH00C02			
WH00C03			
WH00C04			
WH00C05			
WH00C06			
WH00C07			
WH00C08			
WH00C09			
WH00C10			
WH00C11			
WH00C12			
WH00C13			
WH00C14			
WH00C15			
WH00C16			
WH00E01			
WH00E02			
WH00E03			
WH00E04			
WH00E05			
WH00E06			
WH00E07			
WH00E08			
WH00E09			
WH00E10			
WH00E11			
WH00E12			
WH00E13			
WH00E14			
WH00E15			
WH00E16			

Test WH01 – Gas Storage vs. Electric Storage Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		SSF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH01C03						
WH01C09						
WH01C12						
WH01C14						
WH01C16						
WH01E03						
WH01E09						
WH01E12						
WH01E14						
WH01E16						

Test WH02 – Gas Storage vs. Electric Instantaneous Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		SSF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH02C03						
WH02C09						
WH02C12						
WH02C14						
WH02C16						
WH02E03						
WH02E09						
WH02E12						
WH02E14						
WH02E16						

Test WH03 – Pipe Insulation on All Lines

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH03C03						
WH03C09						
WH03C12						
WH03C14						
WH03C16						

Test WH04 – Recirculation Control

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH04E03						
WH04E09						
WH04E12						
WH04E14						
WH04E16						

Test WH05 –Large Gas Storage Water Heater

Label	Water Heating TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH05E03						
WH05E09						
WH05E12						
WH05E14						
WH05E16						

Test WH06 – Recirculation Piping Insulation

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH06E03						
WH06E09						
WH06E12						
WH06E14						
WH06E16						

Test WH07 – Number of Water Heaters

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH07C03						
WH07C09						
WH07C12						
WH07C14						
WH07C16						

Test WH08 – Pump Controls

Label	Water Heating TDV Energy (kBtu/ft²/y)		EF Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
WH08E03						
WH08E09						
WH08E12						
WH08E14						
WH08E16						

RA.5 Water Heating Neutral Variable Tests (WD)

Test WD01 – Increase House Size to 2500ft²

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD01C03					
WD01C09					
WD01C12					
WD01C14					
WD01C16					

Test WD02 – Increase House Size to 3500ft²

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD02C03					
WD02C09					
WD02C12					
WD02C14					
WD02C16					

Test WD03 – Increase Recirculation Piping Length

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD03D03					
WD03D09					
WD03D12					
WD03D14					
WD03D16					

Test WD04 – Change Recirculation Pipe Location

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD04D03					
WD04D09					
WD04D12					
WD04D14					
WD04D16					

Test WD05 – Change to Individual Water Heaters

Label	Water Heating TDV Energy (kBtu/ft²/y)			ACM Filenames	
	Proposed Design Custom Budget	Standard Design Equivalent Custom Budget	Standard Design Equivalent Proposed Design	Proposed Design	Standard Design Equivalent
WD05D03					
WD05D09					
WD05D12					
WD05D14					
WD05D16					

RA.6 Optional Capabilities Tests (OC)

Test OC01 – Dedicated Hydronic Heating

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC01A03						
OC01A09						
OC01A12						
OC01A14						
OC01A16						

Test OC02 – Combined Hydronic, Gas Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC02A03						
OC02A09						
OC02A12						
OC02A14						
OC02A16						

Test OC03 – Combined Hydronic, Electric Resistance Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC03A03						
OC03A09						
OC03A12						
OC03A14						
OC03A16						

Test OC04 – Combined Hydronic, Heat Pump Water Heater.

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC04A03						
OC04A09						
OC04A12						
OC04A14						
OC04A16						

Test OC05 – Control Vent Crawlspace

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC05B03						
OC05B 09						
OC05B 12						
OC05B 14						
OC05B 16						

Test OC06 – Zonal Control

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC06A03						
OC06A09						
OC06A12						
OC06A14						
OC06A16						

Test OC07 – Attached Sunspace

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		AFUE Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC07A03						
OC07A09						
OC07A12						
OC07A14						
OC07A16						

Test OC08 – Exterior Mass Walls

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Wall R-Value Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC08A03						
OC08A09						
OC08A12						
OC08A14						
OC08A16						

Test OC9 – Gas Absorption Cooling

Label	Space Conditioning TDV Energy (kBtu/ft²/y)		Fenestration U-Factor Solution		ACM Filenames	
	Passing Case	Failing Case	Passing Case	Failing Case	Passing Case	Failing Case
OC9A03						
OC9A09						
OC9A12						
OC9A14						
OC9A16						

RA.7 Solar Systems Tests (SS)

Test SS01 – Solar System with Electric Backup

Enter the TDV space conditioning energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS01A03			
SS01A09			
SS01A12			
SS01A14			
SS01A16			

Test SS02 – Solar System with Gas Backup

Enter the TDV space conditioning energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS02A03			
SS02A09			
SS02A12			
SS02A14			
SS02A16			

Test SS03 – Basecase Simulations

Enter the TDV water heating energy for the standard design and the proposed design – values should match.

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS03F01			
SS03F02			
SS03F03			
SS03F04			
SS03F05			
SS03F06			
SS03F07			
SS03F08			
SS03F09			
SS03F10			
SS03F11			
SS03F12			
SS03F13			
SS03F14			
SS03F15			
SS03F16			

Test SS04– Collector Orientation

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS04F03			
SS04F09			
SS04F12			
SS04F14			
SS04F16			

Test SS05– Collector Slope

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS05F03			
SS05F09			
SS05F12			
SS05F14			
SS05F16			

Test SS06– Collector Performance

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS06F03			
SS06F09			
SS06F12			
SS06F14			
SS06F16			

Test SS07– Collector Area

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS07F03			
SS07F09			
SS07F12			
SS07F14			
SS07F16			

Test SS08– Storage Tank Size

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS08F03			
SS08F09			
SS08F12			
SS08F14			
SS08F16			

Test SS10– Circulation Pump

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS10F03			
SS10F09			
SS10F12			
SS10F14			
SS10F16			

Test SS11– Freeze Control

Test Label	TDV Water Heating Energy (kBtu/ft²/y)		ACM Filename
	Standard Design	Proposed Design	
SS11F03			
SS11F09			
SS11F12			
SS11F14			
SS11F16			

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ACM RESIDENTIAL MANUAL APPENDIX RB-2005

Appendix RB – Interior Mass Capacity

RB.1 Scope and Purpose

Interior Mass Capacity (IMC) is a measure of the total thermal mass in a low-rise residential building. IMC is used to determine if a building qualifies as a high mass building. Credit for thermal mass in the *Proposed Design* may only be considered when the *Proposed Design* qualifies as a high mass building. A high mass building is one with thermal mass equivalent to having 30 percent of the conditioned slab floor exposed and 15% of the conditioned non-slab floor exposed two inch thick concrete.

RB.2 Calculating Interior Mass Capacity (IMC)

The IMC for the building is calculated using Equation RB1. The IMC for the building is the sum of the area of each mass material multiplied times its Unit Interior Mass Capacity (UIMC). Table RB-1, Table RB-2, and Table RB-3 give UIMC values for a number of common thermal mass materials. This method allows for multiple mass types common in low-rise residential construction.

Equation RB-1

$$IMC = \sum_{I=1}^{n} A_I \times UIMC_I$$

where

IMC = Interior thermal mass of the building

A_i = Surface area of the i^{th} material

$UIMC_i$ = Unit Interior Mass Capacity (UIMC) of the i^{th} material selected from Table RB-1, Table RB-2, and Table RB-3

N = Number of thermal mass materials in the *Proposed Design*

RB.3 IMC Threshold for a High Mass Building

In order to qualify as a high mass building, the *Proposed Design* must have an IMC greater than or equal to that determined from Equation RD2. The IMC threshold is based on 30% of the conditioned slab area (CSA) being exposed (UIMC=4.6); 70% of the CSA being covered (UIMC=1.8); and 15% of the conditioned non-slab floor area as exposed two inch thick concrete (UIMC=2.5).

Equation RB-2

$$\begin{aligned} IMC_{Threshold} &= 0.3 \times 4.6 \times CSA + 0.7 \times 1.8 \times CSA + 0.15 \times 2.5 \times (CFA - CSA) \\ &= 2.640 \times CSA + 0.375 \times (CFA - CSA) \end{aligned}$$

where:

CSA = Conditioned Slab floor Area

CFA = Total Conditioned Floor Area

Table RB-1 – Interior Mass UIMC Values: Interior Mass[11]- Surfaces Exposed on One Side[13]

Material	Surface Condition	Mass Thickness (inches)	Unit Interior Mass Capacity
Concrete Slab-on-Grade and Raised Concrete Floors	Exposed[1]	2.00	3.6
		3.50	4.6
		6.00	5.1
	Covered[2]	2.00	1.6
		3.50	1.8
		6.00	1.9
Lightweight Concrete[9]	Exposed	0.75	1.0
		1.00	1.4
		1.50	2.0
		2.00	2.5
	Covered	0.75	0.9
		1.00	1.0
		1.50	1.2
		2.00	1.4
Solid Wood[9]	Exposed	1.50	1.2
		3.00	1.6
Tile[3,9]	Exposed	0.50	0.8
		1.00	1.7
		1.50	2.4
		2.00	3.0
Masonry[4,9]	Exposed	1.00	2.0
		2.00	2.7
		4.00	4.2
Adobe[9]	Exposed	4.00	3.8
		6.00	3.9
		8.00	3.9
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.1
	1.00" Gypsum	na	0.5
	0.88" Stucco	na	1.1
Masonry Infill[7]	0.50" Gypsum	3.50	1.3

Table RB-2 – Interior Mass UIMC Values: Interior Mass[11] - Surfaces Exposed on Two Sides[5, 13]

Material	Surface Condition	Mass Thickness (inches)	Unit Interior Mass Capacity
Partial Grout Masonry[4]	Exposed[1]	4.00	6.9
		6.00	7.4
		8.00	7.4
Solid Grout Masonry[4,6]	Exposed	4.00	8.3
		6.00	9.2
		8.00	9.6
Adobe	Exposed	4.00	7.6
		12.00	7.8
		16.00	7.6
Solid Wood/ Logs	Exposed	3.00	3.3
		4.00	3.3
		6.00	3.3
		8.00	3.3
Framed Wall	0.50" Gypsum	na	0.0
	0.63" Gypsum	na	0.2
	1.00" Gypsum	na	0.9
	0.88" Stucco	na	2.1
Masonry Infill[7]	0.50" Gypsum	3.50	2.6

Table RB-3 – Exterior Wall Mass UIMC Values[13]

Material	Surface Condition	Mass Thickness (inches)	Wall U-value	Unit Interior Mass Capacity
Solid Wood/	Exposed[1]	3.00	0.22	0.7
Logs		4.00	0.17	0.9
		6.00	0 .12	1.1
		8.00	0.093	1.2
		10.00	0.075	1.3
		12.00	0.063	1 .3
Wood Cavity Wall[12]	Exposed	3.00[12]	0.11	1.1
			0.065	1.3
			0.045	1.4
Adobe	Exposed	8.00	0.35	2.1
		16.00	0.21	2.8
		24.00	0.15	3.1
Masonry Veneer[4]	Framed Wall	4.00	0.10	na
			0.08	na
			0.06	na
Adobe Veneer	Framed Wall	4.00	0.10	na
			0.08	na
			0.06	na
Partial Grout Masonry[4]	Exposed[1]	4.00	0.68	0.9
			0.58	1.0
		6.00	0.54	1.3
			0.44	1.5
		8.00	0.49	1.5
			0.38	1.7
	Furred[10]	4.00	0.40	0.5
			0.30	0.5
			0.20	0.5
			0.10	0.5
			0.08	0.5
		6.00	0.40	0.9
			0.30	0.6
			0.20	0.5
			0.10	0.5
			0.08	0.5
		8.00	0.30	0.8
			0.20	0.5
			0.10	0.5
			0.08	0.5

Table RB-3: Exterior Wall Mass UIMC Values (continued)[13]

Material	Surface Condition	Mass Thickness (inches)	Wall U-value	Unit Interior Mass Capacity
Solid Grout Masonry[4,6]	Exposed	4.00	0.79	1.0
		6.00	0.68	1.5
		8.00	0.62	1.8
	Furred[10]	4.00	0.40	0.5
			0.30	0.5
			0.20	0.5
			0.10	0.5
			0.08	0.5
		6.00	0.40	0.7
			0.30	0.5
			0.20	0.5
			0.10	0.5
			0.08	0.5
		8.00	0.40	0.8
			0.30	0.6
			0.20	0.5
			0.10	0.5
			0.08	0.5

RB.4 Table Notes

1. "Exposed" means that the mass is directly exposed to room air or covered with a conductive material such as ceramic tile.
2. "Covered" includes carpet, cabinets, closets or walls.
3. The indicated thickness includes both the tile and the mortar bed, when applicable.
4. Masonry includes brick, stone, concrete masonry units, hollow clay tile and other masonry.
5. The unit interior mass capacity for surfaces exposed on two sides is based on the area of one side only.
6. "Solid Grout Masonry" means that all the cells of the masonry units are filled with grout.
7. The indicated thickness for masonry infill is for the masonry material itself.
8. Use the Exterior Mass value for calculating Exterior Wall Mass.
9. Mass located inside exterior walls or ceilings may be considered interior mass (exposed one side) when it is insulated on the exterior with at least R-11 insulation, or a total resistance of R-9 including framing effects.
10. "Furred" means that 0.50-inch gypsum board is placed on the inside of the mass wall separated from the mass with insulation or an air space.
11. When mass types are layered, e.g. tile over slab-on-grade or lightweight concrete floor, only the mass type with the greatest interior mass capacity may be accounted for, based on the total thickness of both layers.
12. This wall consists of 3 inches of wood on each side of a cavity. The cavity may be insulated as indicated by the U-value column.
13. Values based on properties of materials listed in 1993 ASHRAE Handbook of Fundamentals.

ACM RESIDENTIAL MANUAL APPENDIX RC-2005

Appendix RC – Procedures for Field Verification and Diagnostic Testing of Air Distribution Systems

RC.1 Purpose and Scope

ACM RC-2005 contains procedures for measuring the air leakage in forced air distribution systems as well as procedures for verifying duct location, surface area and R-value.

ACM RC-2005 applies to air distribution systems in both new and existing low-rise residential buildings.

ACM RC-2005 provides required procedures for installers, HERS raters and others who need to perform field verification and diagnostic testing to verify the efficiency of air distribution systems. Algorithms for determining distribution system efficiency are contained in Chapter 4 of the residential ACM. Table RC-1 is a summary of the tests and criteria included in ACM RC-2005.

Table RC-1 – Summary of Diagnostic Measurements

Diagnostic	Description	Procedure
Supply Duct Location, Surface Area and R-factor	Verify that duct system was installed according to the design, including location, size and length of ducts, duct insulation R-value and installation of buried ducts.	RC4.1 Diagnostic Supply Duct Location, Surface Area and R-value
Duct Leakage	Verify that duct leakage is less than the criteria or in the case of existing ducts that all accessible leaks have been sealed	RC.4.3 Diagnostic Duct Leakage

RC.2 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

RC2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes as specified by the measurement equipment manufacturer.

RC2.2 Duct Leakage Measurements

The measurement of air flows during duct leakage testing shall have an accuracy of ±3% of measured flow using digital gauges.

RC2.3 Calibration

All instrumentation used for duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

RC.3 Apparatus

RC.3.1 Duct Pressurization

The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section RC2.

RC.3.2 Duct Leakage to Outside (Existing Duct Systems)

The apparatus for measuring duct leakage to outside shall include a fan that is capable of maintaining the pressure within the conditioned spaces in the house 25 Pa relative to the outdoors. The fan most commonly used for this purpose is known as a "blower door", and is typically installed within a temporary seal of an open doorway.

RC.3.3 Smoke-Test of Accessible-Duct Sealing (Existing Duct Systems)

The apparatus for determining and verifying sealing of all accessible ducts shall also include means for introducing controllable amounts of non-toxic visual smoke into the duct pressurization apparatus for identifying leaks in accessible portions of the duct system. Adequate smoke shall be used to assure that any accessible leaks will emit visibly identifiable smoke.

RC.4 Procedures

This section describes procedures that may be used to verify diagnostic inputs for the calculation of improved duct efficiency.

RC.4.1 Diagnostic Supply Duct Location, Surface Area and R-value

The performance calculations in ACM R4 allow credit for duct systems that are designed to be in advantageous locations, with reduced supply duct surface areas and/or higher than default R-values. Compliance credit may be taken for one or more of these duct system improvements in any combination. The procedure in this section is used to verify that the duct system is installed according to the design and meets the requirements for compliance credit.

RC.4.1.1 Duct System Design Requirements

The design shall show the location of equipment and all supply and return registers. The size, R-value, and location of each duct segment shall be shown in the design drawing which shall be cross referenced to the Supply Duct System Details report in the CF1-R. For ducts buried in attic insulation, the portion in contact with the ceiling or deeply buried shall be shown and the design shall include provisions for ducts crossing each other, interacting with the structure, and changing vertical location to connect with elevated equipment or registers as required. Credit shall be allowed for buried ducts only in areas where the ceiling is level and there is at least 6 inches of space between the outer jacket of the installed duct and the roof sheathing above.

RC.4.1.2 Verifying the Duct System Installation

The location of all supply and return registers shall be verified from an inspection of the interior of the dwelling unit. The location of the equipment and the size, R-value and location of each duct segment shall be verified by observation in the spaces where they are located. Deviations from the design shall not be allowed.

RC.4.1.3 Verification for Ducts Buried in Attic Insulation

The procedure of RC4.2.2 shall be carried out prior covering the ducts with insulation. Ducts to be buried shall be insulated to R4.2 or greater. In addition ducts designed to be in contact with the ceiling shall be in continuous contact with the ceiling drywall or ceiling structure not more that 3.5 inches from the ceiling drywall. A sign must be hung near the attic access reading “Caution: Buried Ducts. Markers indicate location of buried ducts.” All ducts which will be completely buried shall have vertical markers which will be visible after insulation installation at not more than every 8 feet of duct length and at the beginning and end of each duct run.

After the ceiling insulation is installed, the R-value and type of insulation listed on the Duct System Details shall be verified. Ceiling insulation shall be level and uniform, mounding at ducts is not allowed.

RC.4.2 System Fan Flow

For the purpose of establishing duct leakage criteria, the total fan flow shall be calculated using RC4.2.1, RC4.2.2 or RC4.2.3.

RC.4.2.1 Default System Fan Flow

Default system fan flow may be used only for homes where the duct system is being tested before the air conditioning and heating system is installed and the equipment specification is not known. For heating only systems the default fan flow shall be 0.5 CFM/CFA. For systems with cooling, the default fan flow shall be 400 CFM per ton of rated cooling capacity calculated by the ACM using the procedure in Appendix RE or the heating only value whichever is greater.

RC.4.2.2 Nominal System Fan Flow

For heating only systems the fan flow shall be 21.7 x Heating Capacity in thousands of Btu/hr. For systems with cooling, the fan flow shall be 400 CFM per nominal ton of rated cooling capacity at ARI conditions or the heating only value whichever is greater.

RC.4.2.3 Measured System Fan Flow

The fan flow shall be shall be as measured according to the procedure in Appendix RE-2005.

RC.4.3 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used by installers and raters to verify that total leakage meets the criteria for any sealed duct system specified in the compliance documents. Diagnostic Duct Leakage from Fan Pressurization of Ducts (Section RC4.3.1) is the only procedure that may be used by a HERS rater to verify duct sealing in a new home. Table RC-2 shows the leakage criteria and test procedures that may be used to demonstrate compliance. In addition to the minimum tests shown, existing duct systems may be tested to show they comply with the criteria for new duct systems.

Table RC-2 Duct Leakage Tests

Case	User and Application	Leakage criteria, % of total fan flow	Procedure
Sealed and tested new duct systems	Installer Testing at Final HERS Rater Testing	6%	RC4.3.1
	Installer Testing at Rough- in, Air Handling Unit Installed	6% Installer Inspection at Final	RC4.3.2.1 RC4.3.2.3
	Installer Testing at Rough-in, Air Handling Unit Not Installed	4% Installer Inspection at Final	RC4.3.2.2 RC4.3.2.3
Sealed and tested altered existing duct system	Installer Testing HERS Rater Testing	15% Total Duct Leakage	RC4.3.1
	Installer Testing HERS Rater Testing	10% Leakage to Outside	RC4.3.3.
	Installer Testing and Inspection HERS Rater Testing and Verification	60% Reduction in Leakage and Inspection and Smoke Test	RC4.3.4 RC4.3.6 and RC4.3.7
	Installer Testing and Inspection HERS Rater Testing and Verification	Fails Leakage Test but All Accessible Ducts are Sealed Inspection and Smoke Test with 100% Verification	RC4.3.5 RC4.3.6 and RC4.3.7

RC.4.3.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The objective of this procedure is for an installer to determine or a rater to verify the total leakage of a new or altered duct system. The total duct leakage shall be determined by pressurizing both the supply and return ducts to a pressure difference of 25 Pascals. The following procedure shall be used for the fan pressurization tests:

1. Verify that the air handler, supply and return plenums and all the connectors, transition pieces, duct boots and registers are installed. The entire duct system shall be included in the total leakage test.
2. For newly installed or altered ducts, verify that cloth backed rubber adhesive duct tape has not been used and if a platform or other building cavity used to house the air distribution system has been newly installed or altered, it contains a duct or is ducted with duct board or sheet metal.
3. Seal all the supply and return registers, except for one return register or the system fan access.
4. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
5. Install a static pressure probe at a supply.
6. Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.
7. Record the flow through the flowmeter, this is the leakage flow at 25 Pascals.
8. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RC-2 the system passes.

When the diagnostic leakage test is performed and the measured total duct leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table R4-13.

RC.4.3.2 Diagnostic Duct Leakage at Rough-in Construction Stage

Installers may determine duct leakage in new construction by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing. When using this measurement technique, the installer shall complete additional inspection (as described in section RC4.3.2.3) of duct integrity after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.

The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The following procedure (either RC4.3.2.1 or RC4.3.2.2) shall be used:

RC.4.3.2.1 For Ducts with the Air Handling Unit Installed and Connected:

For total leakage:

1. Verify that supply and return plenums and all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used to house the air distribution system, it shall contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.
2. Seal all the supply duct boots and return boxes except for one return duct box.
3. Attach the fan flowmeter device at the unsealed duct box.
4. Insert a static pressure probe at one of the sealed supply duct boots.
5. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the duct system and outside or the building space with the entry door open to the outside.
6. Record the flow through the flowmeter, this is the leakage flow at 25 Pascals.
7. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RC2 the system passes..

RC.4.3.2.2 For Ducts with Air Handling Unit Not Yet Installed:

For total leakage:

1. Verify that all the connectors, transition pieces and duct boots have been installed. If a platform or other building cavity is used to house the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.
2. Use a duct connector to connect supply and/or return duct box to the fan flowmeter. Supply and return leaks may be tested separately. If there is only one return register, the supply and return leaks shall be tested at the same time.
3. Seal all the supply duct boots and/or return boxes except for one supply or return duct box.
4. Attach the fan flowmeter device at the unsealed duct box.
5. Insert a static pressure probe at one of the sealed supply duct boots.
6. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the building conditioned space and the duct system.
7. Record the flow through the flowmeter, this is the leakage flow at 25 Pascals.
8. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RC-2 the system passes.

RC.4.3.2.3 Installer Visual Inspection at Final Construction Stage

After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, the following procedure shall be used:

1. Remove at least one supply and one return register, and verify that the spaces between the register boot and the interior finishing wall are properly sealed.
2. If the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed.
3. Inspect all joints to ensure that no cloth backed rubber adhesive duct tape is used.

RC.4.3.3 Duct Leakage to Outside from Fan Pressurization of Ducts

The objective of this test for altered existing duct systems only is to provide an alternate measurement of duct leakage to outdoors. The total duct leakage to outdoors shall be determined by pressurizing the ducts and the conditioned spaces of the house to 25 Pa. The following procedure shall be used for the fan pressurization test of leakage to outside:

1. Seal all the supply and return registers except one return register or the fan access door.
2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
3. Install a static pressure probe at the supply plenum.
4. Attach a blower door to an external doorway.
5. If any ducts are located in an unconditioned basement, all doors or accesses between the conditioned space and the basement shall be closed, and at least one operable door or window (if it exists) between the basement and outside shall be opened during the test.
6. If the ducts are located in a conditioned basement, any door between the basement and the remaining conditioned space shall be opened, and any basement doors or windows to outside must be closed during the test.
7. Adjust the blower door fan to provide 25 Pa [0.1 inches of water] pressure difference between the conditioned space and outside.
8. Adjust the fan/flowmeter to maintain zero pressure (±0.5Pa [±0.002 inches water]) between the ducts and the conditioned space, and adjust the blower door fan to maintain 25 Pa (±0.5Pa) [0.1 inch water (±0.002 inches water)] between the conditioned space and outside. This step may require several iterations.
9. Record the flow through the flowmeter (Q25 [Q0.1]); this is the duct leakage at 25 Pa [0.1 inch water].
10. Divide the leakage flow by the total fan flow and convert to a percentage. If the leakage flow percentage is less than the criteria from Table RC-2 the system passes.

RC.4.3.4 Leakage Improvement from Fan Pressurization of Ducts

For altered existing duct systems which do not pass the Total Leakage (RC4.3.1) or Leakage to Outside (RC4.3.3) tests, the objective of this test is to show that the original leakage is reduced through duct sealing as specified in Table RC-2 The following procedure shall be used:.

1. Use the procedure in RC4.3.1 to measure the leakage before commencing duct sealing.
2. After sealing is complete use the same procedure to measure the leakage after duct sealing.
3. Subtract the sealed leakage from the original leakage and divide the remainder by the original leakage. If the leakage reduction is 60% or greater of the original leakage, the system passes.
4. Complete the Smoke Test specified in RC4.3.6
5. Complete the Visual Inspection specified in RC4.3.7.

RC.4.3.5 Sealing of All Accessible Leaks

For altered existing duct systems that do not pass any of the Total Leakage (RC4.3.1), Leakage to Outside (RC4.3.3) or Leakage Improvement (RC4.3.4) tests, the objective of this test is to show that all accessible leaks are sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

1. Complete each of the leakage tests
2. Complete the Smoke Test as specified in RC4.3.6
3. Complete the Visual Inspection as specified in RC4.3.7.
4. Install required label on the system stating that the system fails the leakage tests.

RC.4.3.6 Smoke-Test of Accessible-Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of the smoke test is to confirm that all accessible leaks have been sealed. The following procedure shall be used:

1. Inject either theatrical or other non-toxic smoke into a fan pressurization device that is maintaining a duct pressure difference of 25 Pa relative to the duct surroundings, with all grilles and registers in the duct system sealed.
2. Visually inspect all accessible portions of the duct system during smoke injection.
3. The system shall pass the test if either of the following conditions are met:
    i. No visible smoke exits the accessible portions of the duct system.; or
    ii. Smoke only emanates from the portion of the HVAC equipment containing the furnace vestibule which is gasketed and sealed by the manufacturer rather than from the ducts.

RC.4.3.7 Visual Inspection of Accessible Duct Sealing

For altered existing ducts that fail the leakage tests, the objective of this inspection in conjunction with the smoke test (RC4.3.6) is to confirm that all accessible leaks have been sealed and that excessively damaged ducts have been replaced. The following procedure shall be used:

1. Visually inspect to verify that the following locations have been sealed:
    - Connections to plenums and other connections to the forced air unit
    - Refrigerant line and other penetrations into the forced air unit
    - Air handler door panel (do not use permanent sealing material, metal tape is acceptable)
    - Register boots sealed to surrounding material
    - Connections between lengths of duct, as well as connections to takeoffs, wyes, tees, and splitter boxes.
2. Visually inspect to verify that portions of the duct system that are excessively damaged have been replaced. Ducts that are considered to be excessively damaged are:
    - Flex ducts with the vapor barrier split or cracked with a total linear split or crack length greater than 12 inches
    - Crushed ducts where cross-sectional area is reduced by 30% or more
    - Metal ducts with rust or corrosion resulting in leaks greater than 2 inches in any dimension
    - Ducts that have been subject to animal infestation resulting in leaks greater than 2 inches in any dimension

ACM RESIDENTIAL MANUAL APPENDIX RD-2005

Appendix RD – Procedures for Determining Refrigerant Charge for Split System Space Cooling Systems without Thermostatic Expansion Valves

RD.1 Purpose and Scope

The purpose of this procedure is to determine and verify that residential split system space cooling systems and heat pumps have the required refrigerant charge. The procedures only apply to ducted split system central air conditioners and ducted split system central heat pumps that do not have thermostatic expansion valves (TXVs). The procedures do not apply to packaged systems. For dwelling units with multiple split systems or heat pumps, the procedure shall be applied to each system separately.

The procedures detailed in ACM Appendix RD-2005 are intended to be used after the HVAC installer has installed and charged the air conditioner or heat pump system in accordance with the manufacturer's instructions and specifications for the specific model equipment installed. The installer shall certify to the builder, building official and HERS rater that he/she has followed the manufacturer's instructions and specifications prior to proceeding with the procedures in this appendix.

Appendix RD-2005 defines two procedures, the Standard Charge Measurement Procedure in Section RD2 and the Alternate Charge Measurement Procedure in Section RD3. The Standard procedure shall be used when the outdoor air temperature is 55°F or above and shall always be used for HERS rater verification. HVAC installers who must complete system installation when the outdoor temperature is below 55°F shall use the Alternate procedure.

The following sections document the instrumentation needed, the required instrumentation calibration, the measurement procedure, and the calculations required for each procedure. Note: Wherever thermocouples appear in this document, thermisters can be used instead with the same requirements applying to thermisters as to thermocouples.

The reference method algorithms adjust (improve) the efficiency of split system air conditioners and heat pumps when they are diagnostically tested to have the correct refrigerant charge or when field verification indicates that a TXV has been installed. Table RD-1 summarizes the algorithms that are affected by refrigerant charge testing or field verification of a TXV.

Table RD-1 – Summary of Diagnostic Measurements

				Proposed Design	
Input to the Algorithms	Variables and Equation Reference	Description	Standard Design Value	Default Value	Procedure
Cooling System Refrigerant Charge	F_{TXV} (Eq. R4-40 and R4-41)	F_{TXV} takes on a value of 0.96 when the system has been diagnostically tested for the correct refrigerant charge. Otherwise, F_{TXV} has a value of 0.90.	Split systems are assumed to have refrigerant charge testing or a TXV, when required by Package D.	No refrigerant charge testing or TXV.	RD2 or RD3

Note that a prerequisite for diagnostically testing the refrigerant charge is to verify that there is adequate airflow over the evaporator coil. This diagnostic test is described in ACM RE-2005.

RD.2 Standard Charge Measurement Procedure

This section specifies the Standard charge measurement procedure. Under this procedure, required refrigerant charge is calculated using the *Superheat Charging Method*. The method also checks airflow across the evaporator coil to determine whether the charge test is valid using the *Temperature Split Method* or the air flow measurement methods in ACM RE-2005.

The Standard procedure detailed in this section shall be completed when the outdoor temperature is 55°F or higher after the HVAC installer has installed and charged the system in accordance with the manufacturer's specifications. If the outdoor temperature is between 55°F and 65°F the return dry bulb temperature shall be maintained above 70°F during the test. All HERS rater verifications are required to use this Standard procedure.

RD.2.1 Minimum Qualifications for this Procedure

Persons carrying out this procedure shall be qualified to perform the following:

- Obtain accurate pressure/temperature readings from refrigeration manifold gauges.
- Obtain accurate temperature readings from thermometer and thermocouple set up.
- Check calibration of refrigerant gauges using a known reference pressure and thermometer/thermocouple set up using a known reference temperature.
- Determine best location for temperature measurements in ducting system and on refrigerant line set.
- Calculate the measured superheat and temperature split.
- Determine the correct level of superheat and temperature split required, based on the conditions present at the time of the test.
- Determine if measured values are reasonable.

RD.2.2 Instrumentation Specifications

Instrumentation for the procedures described in this section shall conform to the following specifications:

RD.2.2.1 Digital Thermometer

Digital thermometer shall have thermocouple compatibility (type K and J) and Celsius or Fahrenheit readout with:

- Accuracy: ±(0.1% of reading + 1.3º F).
- Resolution: 0.2º F.

RD.2.2.2 Thermocouples

Measurements require five (5) heavy duty beaded low-mass wire thermocouples and one (1) cotton wick for measuring wet-bulb temperatures.

RD.2.2.3 Refrigerant Manifold Gauge Set

A standard multiport refrigerant manifold gauge with an accuracy of plus or minus 3% shall be used.

RD.2.3 Calibration

The accuracy of instrumentation shall be maintained using the following procedures. A sticker with the calibration check date shall be affixed to each instrument calibrated.

RD2.3.1 Thermometer/Thermocouple Field Calibration Procedure

Thermometers/thermocouples shall be calibrated monthly to ensure that they are reading accurate temperatures. The following procedure shall be used to check thermometer/thermocouple calibration:

1. Fill an insulated cup (foam) with crushed ice. The ice shall completely fill the cup. Add water to fill the cup.

2. Insert two thermocouples into the center of the ice bath and attach them to the digital thermometer.
3. Let the temperatures stabilize. The temperatures shall be 32°F (+/- 1°F). If the temperature is off by more than 1°F make corrections according to the manufacturer's instructions. Any thermocouples that are off by more than 3°F shall be replaced.
4. Switch the thermocouples and ensure that the temperatures read on T1 and T2 are still within +/- 1°F of 32°F.
5. Affix sticker with calibration check date onto thermocouple.
6. Repeat the process for all thermocouples.

RD.2.3.2 Refrigerant Gauge Field Check Procedure

Refrigerant gauges shall be checked monthly to ensure that the gauges are reading the correct pressures and corresponding temperatures. The following procedure shall be used to check gauge calibration:

1. Place a refrigerant cylinder in a stable environment and let it sit for 4 hours minimum to stabilize to the ambient conditions.
2. Attach a thermocouple to the refrigerant cylinder using duct tape so that there is good contact between the cylinder and the thermocouple.
3. Insulate the thermocouple connection to the cylinder (closed cell pipe insulation can be taped over the end of the thermocouple to provide the insulation).
4. Zero the low side compound gauge with all ports open to atmospheric pressure (no hoses attached).
5. Re-install the hose and attach the low side gauge to the refrigerant cylinder.
6. Read the temperature of the thermocouple.
7. Using a pressure/temperature chart for the refrigerant, look up the pressure that corresponds to the temperature measured.
8. If gauge does not read the correct pressure corresponding to the temperature, the gauge is out of calibration and needs to be replaced or returned to the manufacturer for calibration.
9. Repeat the process in steps 4 through 8 for the high side gauge.
10. Affix sticker with calibration check date onto refrigerant gauge.

RD.2.4 Charge Measurement

The following procedure shall be used to obtain measurements necessary to adjust required refrigerant charge as described in the following sections:

1. If the condenser air entering temperature is less than 65°F, establish a return air dry bulb temperature sufficiently high that the return air dry bulb temperature will be not less than 70°F prior to the measurements at the end of the 15 minute period in step 2.
2. Turn the cooling system on and let it run for 15 minutes to stabilize temperatures and pressures before taking any measurements. While the system is stabilizing, proceed with setting up the temperature measurements.
3. Connect the refrigerant gauge manifold to the suction line service valve.
4. Attach a thermocouple to the suction line near the suction line service valve. Be sure the sensor is in direct contact with the line and is well insulated from air temperature.
5. Attach a thermocouple to measure the condenser (entering) air dry-bulb temperature. The sensor shall be placed so that it records the average condenser air entering temperature and is shaded from direct sun.
6. Be sure that all cabinet panels that affect airflow are in place before making measurements. The thermocouple sensors shall remain attached to the system until the final charge is determined.

7. Place wet-bulb thermocouple in water to ensure it is saturated when needed. **Do not get the dry-bulb thermocouples wet.**
8. Insert the dry-bulb thermocouple in the supply plenum at the center of the airflow.
9. At 12 minutes, insert a dry-bulb thermocouple and a wet-bulb thermocouple into the return plenum at the center of the airflow.
10. At 15 minutes when the return plenum temperatures have stabilized, using the thermocouples already in place, measure and record the return (evaporator entering) air dry-bulb temperature ($T_{return, db}$) and the return (evaporator entering) air wet-bulb temperature ($T_{return, wb}$).
11. Using the dry-bulb thermocouple already in place, measure and record the supply (evaporator leaving) air dry-bulb temperature ($T_{supply, db}$).
12. Using the refrigerant gauge already attached, measure and record the evaporator saturation temperature ($T_{evaporator, sat}$) from the low side gauge.
13. Using the dry-bulb thermocouple already in place, measure and record the suction line temperature ($T_{suction, db}$).
14. Using the dry-bulb thermocouple already in place, measure and record the condenser (entering) air dry-bulb temperature ($T_{condenser, db}$).

The above measurements shall be used to adjust refrigerant charge and airflow as described in following sections.

RD.2.5 Refrigerant Charge Calculations

The Superheat Charging Method is used only for non-TXV systems equipped with fixed metering devices. These include capillary tubes and piston-type metering devices. The following steps describe the calculations to determine if the system meets the required refrigerant charge using the measurements described in Section RD2.4. If a system fails, then remedial actions must be taken. If the refrigerant charge is changed and the airflow has been previously tested and shown to pass, then the airflow shall be re-tested. Be sure to complete Steps 1 and 2 of Section RD2.4 before re-testing the airflow. Both the airflow and charge must be re-tested until they both sequentially pass.

1. Calculate Actual Superheat as the suction line temperature minus the evaporator saturation temperature.

   Actual Superheat = $T_{suction, db} – T_{evaporator, sat}$.
2. Determine the Target Superheat using Table RD2 using the return air wet-bulb temperature ($T_{return, wb}$) and condenser air dry-bulb temperature ($T_{condenser, db}$).
3. If a dash mark is read from Table RD-2, the target superheat is less than 5°F, then the system **does not pass** the required refrigerant charge criteria, usually because outdoor conditions are too hot and dry. One of the following adjustments is needed until a target superheat value can be obtained from Table RD-2 by either 1) turning on the space heating system and/or opening the windows to warm up indoor temperature; or 2) retest at another time when conditions are different. After adjustments, repeat the measurement procedure as often as necessary to establish the target superheat. Allow system to stabilize for 15 minutes before completing the measurement procedure again.
4. Calculate the difference between actual superheat and target superheat (Actual Superheat - Target Superheat)
5. If the difference is between minus 5 and plus 5°F, then the system **passes** the required refrigerant charge criteria.
6. If the difference is greater than plus 5°F, then the system **does not pass** the required refrigerant charge criteria and the installer shall add refrigerant. After the refrigerant has been added, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement procedure as many times as necessary to pass the test.

7. If the difference is between –5 and -100°F, then the system **does not pass** the required refrigerant charge criteria, the installer shall remove refrigerant. After the refrigerant has been removed, turn the system on and allow it to stabilize for 15 minutes before completing the measurement procedure again. Adjust refrigerant charge and repeat the measurement as many times as necessary to pass the test.

RD.2.6 Airflow Verification

In order to have a valid charge test, the air flow shall be verified by either passing the temperature split test or by one of the three measurements in ACM Appendix RE-2005 with a measured airflow in excess of 0.033 cfm/Btu capacity rated at DOE A test conditions (400 cfm/12000 Btu) (dry coil).

The temperature split test method is designed to provide an efficient check to see if airflow is above the required minimum for a valid refrigerant charge test. The following steps describe the calculations using the measurement procedure described in Section RD2.4. If a system fails, then remedial actions must be taken. If the airflow is changed and the refrigerant charge has previously been tested and shown to pass, then the refrigerant charge shall be re-tested. Be sure to complete Steps 1 and 2 of Section RD2.4 before re-testing the refrigerant charge. Both the airflow and charge must be re-tested until they both sequentially pass.

1. Calculate the Actual Temperature Split as the return air dry-bulb temperature minus the supply air dry-bulb temperature. Actual Temperature Split = $T_{return, db} - T_{supply, db}$
2. Determine the Target Temperature Split from Table RD-3using the return air wet-bulb temperature ($T_{return, wb}$) and return air dry-bulb temperature ($T_{return, db}$).
3. If a dash mark is read from Table RD-3, then there probably was an error in the measurements because the conditions in this part of the table would be extremely unusual. If this happens, re-measure the temperatures. If re-measurement results in a dash mark, complete one of the alternate airflow measurements in Section RE4.1.
4. Calculate the difference between target and actual temperature split (Actual Temperature Split-Target Temperature Split). If the difference is within plus 3°F and minus 3°F, then the system **passes** the adequate airflow criteria.
5. If the difference is greater than plus 3°F, then the system **does not pass** the adequate airflow criteria and the airflow shall be increased by the installer. Increasing airflow can be accomplished by eliminating restrictions in the duct system, increasing blower speed, cleaning filters, or opening registers. After corrective measures are taken, repeat measurement procedure as often as necessary to establish adequate airflow range. Allow system to stabilize for 15 minutes before repeating measurement procedure.
6. If the difference is between minus 3°F and minus 100°F, then the measurement procedure shall be repeated making sure that temperatures are measured at the center of the airflow.
7. If the re-measured difference is between plus 3°F and minus 3°F the system **passes** the adequate airflow criteria. If the re-measured difference is between minus 3°F and minus 100°F, the system passes, but it is likely that the capacity is low on this system (it is possible, but unlikely, that airflow is higher than average).

RD.3 Alternate Charge Measurement Procedure

This section specifies the Alternate charge measurement procedure. Under this procedure, the required refrigerant charge is calculated using the *Weigh-In Charging Method*.

HVAC installers who must complete system installation verification when the outdoor temperature is below 55°F shall use this Alternate procedure in conjunction with installing and charging the system in accordance with the manufacturer's specifications. HERS Raters shall not use this procedure to verify compliance.

Split system air conditioners come from the factory already charged with the standard charge indicated on the name plate. The manufacturer supplies the charge proper for the application based on their standard liquid line length. It is the responsibility of the HVAC installer to ensure that the charge is correct for each air conditioner and to adjust the charge based on liquid line length different from the manufacturer's standard.

RD.3.1 Minimum Qualifications for this Procedure

HVAC installation technicians shall be qualified to perform the following:

1. Transfer and recovery of refrigerant (including a valid Environmental Protection Agency (EPA) certification for transition and recovery of refrigerant).
2. Accurately weigh the amount of refrigerant added or removed using an electronic scale.
3. Calculate the refrigerant charge adjustment needed to compensate for non-standard lineset lengths/diameters based on the actual lineset length/diameter and the manufacturer's specifications for adjusting refrigerant charge for non-standard lineset lengths/diameters.

RD.3.2 Instrumentation Specifications

The digital scale used to weigh in refrigerant must have a range of .5 oz to at least 1200 oz (75 lb.). The scale's accuracy must be ± 0.25 oz.

RD.3.3 Weigh-In Method

The following procedure shall be used by the HVAC installer to charge the system with the correct refrigerant charge.

1. Obtain manufacturer's standard liquid line length and charge adjustment for alternate liquid line lengths.
2. Measure and record the actual liquid line length (L_{actual}).
3. Record the manufacturer's standard liquid line length ($L_{standard}$).
4. Calculate the difference between actual and standard liquid line lengths

   ($L_{actual} - L_{standard}$).
5. Record the manufacturer's adjustment for liquid line length difference per foot (A_{length}).
6. Calculate the amount of refrigerant to add or remove and document the calculations on the CF-6R.
7. Weigh in or remove the correct amount of refrigerant

Table RD-2: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Condenser Air Dry-Bulb Temperature (°F)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7
84	-	-	-	-	-	-	-	-	-	-	5.5	7.4	9.2	10.9	12.5	14.3	16.1	17.8	19.6	21.3	23.0	24.8	26.5	28.2	29.9	31.6	33.3
85	-	-	-	-	-	-	-	-	-	-	-	6.6	8.5	10.3	11.9	13.7	15.5	17.3	19.0	20.8	22.6	24.3	26.0	27.8	29.5	31.2	32.9
86	-	-	-	-	-	-	-	-	-	-	-	5.8	7.8	9.6	11.3	13.2	15.0	16.7	18.5	20.3	22.1	23.8	25.6	27.3	29.1	30.8	32.6
87	-	-	-	-	-	-	-	-	-	-	-	5.0	7.0	8.9	10.6	12.6	14.4	16.2	18.0	19.8	21.6	23.4	25.1	26.9	28.7	30.4	32.2
88	-	-	-	-	-	-	-	-	-	-	-	-	6.3	8.2	10.0	12.0	13.9	15.7	17.5	19.3	21.1	22.9	24.7	26.5	28.3	30.1	31.8
89	-	-	-	-	-	-	-	-	-	-	-	-	5.5	7.5	9.4	11.5	13.3	15.1	17.0	18.8	20.6	22.4	24.3	26.1	27.9	29.7	31.5
90	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.8	14.6	16.5	18.3	20.1	22.0	23.8	25.6	27.5	29.3	31.1

Greyed area indicates test conditions where the return drybulb temperature must exceed 70°F

Table RD-2: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature) (continued)

		Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
		50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
Condenser Air Dry-Bulb Temperature (°F)	91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
	92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
	93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13.0	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.7
	95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10.0	12.0	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
	96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29.0
	97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
	98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
	99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24.0	26.0	28.0
	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
	101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15.0	17.0	19.1	21.1	23.2	25.3	27.3
	102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27.0
	103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14.0	16.1	18.2	20.3	22.4	24.5	26.7
	104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
	105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11.0	13.1	15.2	17.4	19.5	21.7	23.8	26.0
	106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17.0	19.1	21.3	23.5	25.7
	107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10.0	12.2	14.4	16.6	18.7	21.0	23.2	25.4
	108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
	109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18.0	20.2	22.5	24.7
	110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4
	111	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	8.1	10.4	12.6	14.9	17.2	19.5	21.8	24.1
	112	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.6	9.9	12.2	14.5	16.8	19.1	21.5	23.8
	113	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.2	9.5	11.8	14.1	16.4	18.8	21.1	23.5
	114	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	9.0	11.4	13.7	16.1	18.4	20.8	23.2
	115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.6	10.9	13.3	15.7	18.1	20.5	22.9

Table RD-3: Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry–Bulb (ºF) ($T_{return, db}$)	Return Air Wet-Bulb (ºF) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

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ACM RESIDENTIAL MANUAL APPENDIX RE-2005

Appendix RE – Field Verification and Diagnostic Testing of Forced Air System Fan Flow and Air Handler Fan Watt Draw

RE.1 Purpose and Scope

ACM RE-2005 contains procedures for verifying adequate airflow in split system and packaged air conditioning systems serving low-rise residential buildings. The procedure is also used to verify reduced fan watts achieved through improved air distribution design, including more efficient motors and air distribution systems with fewer obstructions. The refrigerant charge test described in ACM RE requires as a prerequisite that adequate airflow be verified. In addition, the reference method algorithms offer a credit for low fan power which can be obtained through diagnostic measurements. Table RE-1 summarizes the diagnostic measurement procedures in ACM Appendix RE-2005 and shows their relationship to the equipment efficiency algorithms in ACM Chapter 4.

Table RE-1 – Summary of Diagnostic Measurements

Input to the Algorithms	Variables and Equation Reference	Description	Standard Design Value	Proposed Design	
				Default Value	Procedure
Fan Power Ratio	FanW/Btu (Eq. R4-49)	The ratio of fan power in Watts to the cooling capacity in Btu/h.	0.051 W/Btu.	0.051 W/Btu.	Section RE4.3
Fan Flow over Evaporator	F_{air} (Eq. R4-40 and R4.41)	The term F_{air} depends on the measured airflow over the evaporator coil. A value of 0.925 is used as a default, but a value of 1.000 can be used if	F_{air} = 1.000 when refrigerant charge testing or TXV is required by Package D.	F_{air} = 0.925	Section RE4.1
Refrigerant Charge Prerequisite	n. a.	An airflow of at least 350 cfm/ton must be maintained over a wet coil or 400 cfm/ton over a dry coil before a valid refrigerant charge test may be performed	n. a.	n. a.	Section RE4.1

RE.2 Instrumentation Specifications

The instrumentation for the diagnostic measurements shall conform to the following specifications:

RE.2.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

RE.2.2 Fan Flow Measurements

All measurements of distribution fan flows shall be made with measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 7% reading or ± 5 cfm whichever is greater.

RE.2.3 Watt Measurements

All measurements of air handler watt draws shall be made with true power measurement systems (i.e., sensor plus data acquisition system) having an accuracy of ± 2% reading or ± 10 watts whichever is greater.

RE.3 Apparatus

RE.3.1 System Fan Flows

HVAC system fan flow shall be measured using one of the following methods.

RE.3.1.1 Plenum Pressure Matching Measurement

The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter) meeting the specifications in RE2.2, a static pressure transducer meeting the specifications in Section RE2.1, and an air barrier between the return duct system and the air handler inlet. The measuring device shall be attached at the air handler blower compartment door. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.

RE.3.1.2 Flow Capture Hood Measurement

A flow capture hood meeting the specifications in Section RE2.2 may be used to verify the fan flow at the return register(s). All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).

RE.3.1.3 Flow Grid Measurement

The apparatus for measuring the system fan flow shall consist of a flow measurement device (subsequently referred to as a fan flow grid) meeting the specifications in RE2.2 and a static pressure transducer meeting the specifications in Section RE2.1. The measuring device shall be attached at a point where all the fan airflow shall flow through the flow grid. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.

RE.3.2 Air Handler Watts

The air handler watt draw shall be measured using one of the following methods.

RE.3.2.1 Portable Watt Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of a watt meter meeting the specifications in RE2.3. The measuring device shall be attached to measure the air handler fan watt draw. All registers shall be in their normal operating condition.

RE.3.2.2 Utility Revenue Meter Measurement

The apparatus for measuring the air handler watt draw shall consist of the utility revenue meter meeting the specifications in RE2.3 and a stopwatch measuring in seconds. All registers shall be in their normal operating condition.

RE.4 Procedure

To determine and verify airflow credit a diagnostic fan flow measurement shall demonstrate air flow greater than the criteria and installation of the duct system must be designed to meet the criteria in RE4.2.

To determine and verify airflow and fan watt draw credit, in addition to verifying air flow, the air handler fan watt draw measurement shall show fan watts less than that claimed in ACM calculations and shown in CF-1R.

RE.4.1 Diagnostic Fan Flow

Table RE-2 – Airflow Criteria
Note: All airflows are for the fan set at the speed used for air conditioning.

Test and Condition	Cooling air flow (Wet Coil)	Test Flow if Dry Coil
Airflow needed for compliance credit	400 cfm/ton	450 cfm/ton

The system passes the fan flow test if the fan flow measured using one of the following methods is greater than the criteria in Table RE2. The Wet Coil criteria shall be used if the air conditioner is operating and conditions are such that the coil is wet. Otherwise the Dry coil criteria shall be used

RE.4.1.1 Diagnostic Fan Flow Using Flow Capture Hood

The fan flow measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and measure the fan flow at the return grille(s) with a calibrated flow capture hood to determine the total system return fan flow. The system fan flow (Qah, cfm) shall be the sum of the measured return flows.

RE.4.1.2 Diagnostic Fan Flow Using Plenum Pressure Matching

The fan flow measurement shall be performed using the following procedures:

1. If the fan flowmeter is to be connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.
2. With the system fan on at the maximum speed used in the installation (usually the cooling speed when air conditioning is present), measure the pressure difference (in pascal) between the supply plenum and the conditioned space (Psp). Psp is the target pressure to be maintained during the fan flow tests. If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.3. Block the return duct from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.
3. Attach the fan flowmeter device to the duct system at the air handler. For many air handlers, there will be a removable section that allows access to the fan that is suitable for this purpose.
4. Turn on the system fan and the fan flow meter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches Psp.
5. Record the flow through the flowmeter (Qah, cfm) - this is the diagnostic fan flow. In some systems, typical system fan and fan flowmeter combinations may not be able to produce enough flow to reach Psp. In this case record the maximum flow (Qmax, cfm) and pressure (Pmax) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Qmax and Pmax) to operating condition at operating pressure (Psp).

Equation RE-1 Air Handler Flow Qah = Qmax x (Psp/Pmax) ^.5

RE.4.1.3 Diagnostic Fan Flow Using Flow Grid Measurement

The fan flow measurement shall be performed using the following procedures:

1. With the system fan on at the maximum speed used in the installation (usually the cooling speed when air conditioning is present measure the pressure difference (in pascal) between the supply plenum and the conditioned space (Psp). If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.
2. The flow grid shall be attached at a point where all the fan air flows through the flow grid.
3. Re-measure the system operating pressure with the flow grid in place.

4. Measure the air flow through the flow grid (Qgrid) and the test pressure (Ptest).

5. The following equation for air handler flow shall be used to correct flow through the flow grid and pressure (Qgrid and Ptest) to operating condition at operating pressure (Psp).

Equation RE-2 $$Qah = Qmax \times (Psp/Ptest)^{.5}$$

RE.4.2 Duct Design

The duct system installation shall be verified to be consistent with the design meeting the following requirements. The duct system shall be designed to meet the airflow rate with the available external static pressure from the air handler at that airflow. The duct design shall have calculations showing the duct system will operate at equal to or greater than 0.0375 cfm/Btu rated capacity at ARI test condtions (450 cfm/12000 Btu) in cooling speed (dry coil) or, if heating only, equal to or greater than 16.8 cfm per 1000 Btu/hr furnace output. The design shall be based on the available external static pressure from the air handler, the pressure drop of external devices, the equivalent length of the runs, as well as the size, type and configuration of the ducts. The duct layout shall be included on the plans and the duct design shall be reported on the CF-6R and posted on-site.

RE.4.3 Diagnostic Air Handler Watt Draw

The system passes the Watt Draw test if the air handler watt draw is less than or equal to the value claimed in compliance calculations and reported by the ACM on the CF-1R. The diagnostic air handler watt draw shall be measured using one of the following methods:

RE.4.3.1 Diagnostic Air Handler Watt Draw Using Portable Watt Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and measure the fan watt draw (Wfan).

RE.4.3.2 Diagnostic Air Handler Watt Draw Using Utility Revenue Meter

The air handler watt draw measurement shall be performed using the following procedures; all registers shall be fully open, and the air filter shall be installed. Turn on the system fan at the maximum speed used in the installation (usually the cooling speed when air conditioning is present) and turn off every circuit breaker except the one exclusively serving the air handler. Record the Kh factor on the revenue meter, count the number of full revolutions of the meter wheel over a period exceeding 90 seconds. Record the number of revolutions (Nrev) and time period (trev, seconds). Compute the air handler watt draw (Wfan) using the following formula:

Equation RE-3 Air Handler Fan Watt Draw $$Wfan = (Kh \times Nrev \times 3600) / trev$$

Return all circuit breakers to their original positions.

ACM RESIDENTIAL MANUAL APPENDIX RF-2005

Appendix RF – HVAC Sizing

RF.1 Purpose and Scope

ACM RF-2005 is a procedure for calculating the cooling load in low-rise residential buildings (Section RF2) and for determining the maximum cooling capacity for credit in ACM calculations (Section RF3). Section RF4 has a procedure for determining compliance for oversized equipment by showing that the peak power is equal to or less than equipment that minimally meet the requirements of this section.

RF.2 Procedure for Calculating Design Cooling Capacity

The following rules apply when calculating the design cooling:

RF.2.1 Methodology

The methodologies, computer programs, inputs, and assumptions approved by the commission shall be used.

RF.2.2 Cooling Loads

Except as specified in this section, calculations will be done in accordance with the method described in Chapter 28, Residential Cooling and Heating Load Calculations, 2001 ASHRAE Fundamentals Handbook. Interpolation shall be used with tables in Chapter 28. The methods in Chapter 29 may not be used under this procedure.

RF.2.3 Indoor Design Conditions

The indoor cooling design temperature shall be 75°F. An indoor design temperature swing of 3°F shall be used.

RF.2.4 Outdoor Design Conditions

Outdoor design conditions shall be selected from the 1.0 Percent Cooling Dry Bulb and Mean Coincident Wet Bulb values in Joint Appendix II REF.

RF.2.5 Block Loads

The design cooling capacity used for calculating the maximum allowable cooling capacity is based on the block (peak) load either for

1. The whole building; or
2. For each zone within a building that is served by its own cooling system; or
3. For each dwelling unit within a building that is served by its own cooling system.

Room-by-room loads are not allowed for calculating the design cooling capacity.

RF.2.6 Table Selection

Tables 2 (cooling load temperature differences) and 4 (glass load factors) shall be used for:

1. Buildings with more than one dwelling unit using whole building block loads; or
2. Buildings or zones with either east or west exposed walls but not both east and west exposed walls.

Otherwise, Tables 1 (cooling load temperature differences) and 3 (glass load factors) shall be used.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RF.2.7 U-factors

U-factors for all opaque surfaces and fenestration products shall be consistent with the methods described in Section 4.2 and Section 4.3 of the Residential ACM Manual. The effects of radiant barriers or cool roofs shall be included if these features are in the proposed building.

RF.2.8 Solar Heat Gain Coefficients

Solar heat gain coefficients (SHGC) shall be equal to the $SHGC_{closed}$ values described in Section 4.3.4 of the Residential ACM Manual.

RF.2.9 Glass Load Factors

Glass load factors (GLFs) shall be calculated using the equation in the footnotes of Tables 3 and 4 in Chapter 28 using the columns for “Regular Double Glass” and the rows for “Draperies, venetian blinds, etc”. The table values used in the equation shall be U_t = 0.55 and SC_t = 0.45. The shading coefficient for the alternate value shall be SC_a = SHGC x 0.87 where the SHGC value is described above. The GLF values shall also be adjusted for latitude as described in the footnotes.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RF.2.10 Infiltration

The air flow (CFM) due to infiltration and mechanical ventilation shall be calculated with the effective leakage area method as documented in Section 4.5.1 of the Residential ACM Manual using the outdoor design temperature minus the indoor design temperature as the temperature difference and a 7.5 mph wind speed.

RF.2.11 Internal Gain

Occupancy shall be assumed to be two persons for the first bedroom and one person for each additional bedroom per dwelling unit. Each person shall be assigned a sensible heat gain of 230 Btu/hr. Appliance loads shall be 1200 Btu/hr for multifamily buildings with common floors and ceilings. Otherwise the appliance load is 1600 Btu/hr.

RF.2.12 Cooling Duct Efficiency

The cooling duct efficiency shall be calculated using the seasonal approach as documented in ACM Section 4.8.8.

RF.2.13 Latent Factor.

The latent factor shall be 1.0.

RF.2.14 Total Cooling Load

The total cooling load is calculated in accordance with Table 9 of Chapter 28 of the ASHRAE Handbook, Fundamentals Volume, 2001, using the values specified in this section.

RF.2.15 Design Cooling Load

The design cooling load is equal to the total cooling load divided by the cooling duct efficiency.

RF.2.16 Design Cooling Capacity

The design cooling capacity calculation adjusts the sensible design cooling load to estimate the rated cooling capacity needed as follows:

Equation RF-1

$$\text{Design Cooling Capacity (Btu/hr)} = \text{Design Cooling Load (Btu/hr)} \times (0.8192 + 0.0038 \times \text{Outdoor Cooling Design Temperature } (°F))$$

RF.3 Procedure for Calculating Maximum Cooling Capacity for ACM Credit

The following rules apply when calculating the maximum cooling capacity for ACM credit:

RF.3.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RF2.

RF.3.2 Maximum Cooling Capacity for ACM Credit

For buildings with a single cooling system or for buildings where the design cooling capacity has been calculated separately for each cooling system, the maximum cooling capacity for ACM credit for each cooling system shall be:

Table RF-1 – Maximum Cooling Capacity for ACM Credit

Design Cooling Capacity (Btu/hr)		Maximum Cooling Capacity for ACM Credit (Btu/hr)
< 48000		Design Cooling Capacity + 6000
48000 - 60000		Design Cooling Capacity + 12000
>60000		Design Cooling Capacity + 30000

For buildings with more than one cooling system where the design cooling capacity has been calculated for the entire building, the maximum cooling capacity for ACM credit for the entire building shall be:

Equation RF-2

$$\text{Maximum Cooling Capacity for ACM Credit (Btu/hr)} = \text{Design Cooling Capacity (Btu/hr)} + (6000 \text{ (Btu/hr)} \times \text{Number of Cooling Systems})$$

RF.3.3 Multiple Orientations

For buildings demonstrating compliance using the multiple orientation alternative of Section 151(c), the maximum cooling capacity for ACM credit is the highest, considering north, northeast, east, southeast, south, southwest, west and northwest orientations. For buildings with more than one cooling system, the orientation used for determining the maximum cooling capacity for ACM credit shall be permitted to be different for each zone.

RF.4 Procedure for Determining Electrical Input Exception for Maximum Cooling Capacity for ACM Credit

The installed cooling capacity shall be permitted to exceed the maximum cooling capacity for ACM credit if the electrical input of the oversized cooling system is less than or equal to the electrical input of a standard cooling system using the following rules:

RF.4.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RF2.

RF.4.2 Standard Total Electrical Input

The standard electrical input is calculated as follows:

Equation RF-3	Standard Total Electrical Input (W) = 0.1170.1048 (W/Btu/hr) x Design Cooling Capacity (Btu/hr)

RF.4.3 Proposed Electrical Input

The proposed electrical input (W) for the installed cooling system is calculated as follows:

Equation RF-4	Proposed Compressor Electrical Input (W) = Electrical Input (W) - (.0122 * Design Cooling Capacity (Btu/hr))

Where "Electrical Input" is as published in the Directories of Certified Appliances maintained by the California Energy Commission in accordance with the requirements of the Appliance Standards.

The proposed electrical input (W) for the installed cooling system is published as the "Electrical Input" in the Directories of Certified Appliances maintained by the California Energy Commission in accordance with the requirements of the Appliance Standards.

RF.4.4 Proposed Fan Power

The proposed fan power (W) of the installed cooling system is equal to either:

1. 0.017 (W/Btu/hr) x Design Cooling Capacity (Btu/hr); or
2. The measured fan power (W) where the measured fan power is determined using the procedure described in ACM RE-2005 of the *Residential ACM Manual*.

RF.4.5 Proposed Total Electrical Input

The proposed electrical input is equal to:

Equation RF-5	Proposed Total Electrical Input (W) = Proposed Electrical Input (W) + Proposed Fan Power (W)

For buildings with more than one cooling system, the proposed total electrical power shall be the sum of the values for each system. If the proposed total electrical input is less than or equal to the standard total electrical input, then the installed cooling capacity may exceed the allowable cooling capacity for ACM credit.

ACM RESIDENTIAL MANUAL APPENDIX RG-2005

Appendix RG – Water Heating Calculation Method

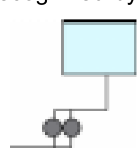
RG.1 Purpose and Scope

ACM RG documents the methods and assumptions used for calculating the hourly energy use for residential water heating systems for both the proposed design and the standard design. The hourly fuel and electricity energy use for water heating will be combined with hourly space heating and cooling energy use to come up with the hourly total fuel and electricity energy use to be factored by the hourly TDV energy multiplier. The calculation procedure applies to low-rise single family, low-rise multi-family, and high-rise residential.

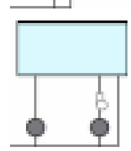
When buildings have multiple water heaters, the hourly total water heating energy use is the hourly water heating energy use summed over all water heating systems, all water heaters, and all dwelling units being modeled.

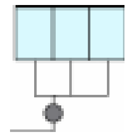
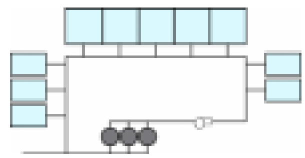
The following diagrams illustrate some of the cases that are recognized by ACM.

1 One distribution system with two water heaters serving a single dwelling unit.



2 Two distribution systems, each with a single water heater serving a single dwelling unit.



3	One distribution system with one water heater serving multiple dwelling units.	
4	Single distribution system with multiple water heaters serving multiple units.	

The following rules apply to the calculation of water heating system energy use:

- One water heater type per system, e.g. no mix of gas and electric water heaters in the same system
- One solar or woodstove credit (but not both) per system

RG.2 Water Heating Systems

Water heating distribution systems may serve more than one dwelling unit and may have more than one piece of water heating equipment. The energy used by a water heating system is calculated as the sum of the energy used by each individual water heater in the system. Energy used for the whole building is calculated as the sum of the energy used by each of the water heating systems. To delineate different water heating elements several indices are used.

i Used to describe an individual dwelling unit. For instance CFAi would be the conditioned floor area of the i^{th} dwelling unit. "N" is the total number of dwelling units.

j Used to refer to the number of water heaters in a system. "M" is the total number of water heaters.

k Used to refer to a water heating system or distribution system. A building can have more than one system and each system can have more than one water heater.

RG.3 Hourly Adjusted Recovery Load

The hourly adjusted recovery load (HARL) can be calculated by Equation RG-1 through Equation RG-6.

Equation RG-1
$$HARL_k = HSEU_k \times DLM_k \times SSM_k + HRDL_k$$

This equation calculates the hourly recovery load on the water heater. The hourly adjusted recovery load (HARL) is the heat content of the water delivered at the fixture (HSEU) times the distribution loss multiplier (DLM) times the solar saving multiplier (SSM) plus the hourly recirculation losses between dwelling units (HRDL), which only occurs for multi-family central water heating systems and is zero for single family dwellings. The DLM will generally be greater than one, which means that heat is wasted as water flows from the water heater to the fixture. The DLM_k is constant for all hours with water heating end use. SSM_k is the solar savings multiplier for all solar systems. The methods for determining SSM_k for systems using SRCC OG 300 rating methods are in Section RG 3.4.1 and for systems using SRCC OG 100 rating methods are in Section RG 3.4.2.

Equation RG-2
$$HSEU_k = 8.345 \times GPH_k \times \Delta T$$

This equation calculates the hourly standard end use (HSEU) for each hour at all fixtures. The heat content of the water delivered at the fixture is the draw volume in gallons (GPH) times the temperature rise ΔT (difference between the cold water inlet temperature and the hot water supply temperature) times the heat required to elevate a gallon of water 1ºF (the 8.345 constant). GPH are calculated in a manner consistent with the

Standard Recovery Load values in the current water heating methodology (see RG.3.2.1 Pipe Insulation Eligibility Requirements).

Equation RG-3 $$\Delta T = T_S - T_{inlet}$$

Temperature difference (ºF) between cold water inlet temperature T_{inlet} and the hot water supply temperature T_s.

Equation RG-4 $$DLM_k = 1 + (SDLM_k - 1) \times DSM_k$$

This is the equation for the distribution loss multiplier. It combines two terms: the standard distribution loss multiplier (SDLM), which depends on the size of the dwelling unit and the number of stories, and the distribution system multiplier (DSM) listed in Table RG-2. For point-of-use (POU) distribution systems located in close proximity to all hot water fixtures (see RG.3.2.1 Pipe Insulation Eligibility Requirements), DLM is equal to one, e.g. there are no distribution losses.

Equation RG-5 $$SDLM_k = 1.064 + 0.000084 \times CFA_k$$

This equation gives the standard distribution loss multiplier (SDLM) for one story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). Multi-family SDLM's will be calculated based on the one story equation and the average CFA for all units. CFA_k is capped at 2500 ft^2 for all single and multi-family units.

Equation RG-6 $$SDLM_k = 1.023 + 0.000056 \times CFA_k$$

This equation gives the standard distribution loss multiplier (SDLM) for two and three story dwelling units, based on CFA_k (equal to the total CFA divided by the number of water heaters per dwelling unit). CFA_k is capped at 2500 ft^2 for all single and multi-family units.

Equation RG-7 $$SSM_k = 1 - SSF_k \times A$$

This equation gives the solar savings multiplier (unitless) for the k^{th} water heating system. Equation RG-11 and Equation RG-12 provide more detail. SSF_k is the same as SF in Equation 12 (for OG 100) and as the solar collector's component of the SEF in Equation 11 (for OG 300).

where

$HARL_k$ = Hourly adjusted recovery load (Btu).

$HSEU_k$ = Hourly standard end use (Btu). This is the amount of heat delivered at the hot water fixtures relative to the cold water inlet temperature.

$HRDL_k$ = Hourly recirculation distribution loss (Btu) is the hot water energy loss in multi-family central water heating recirculation systems (See RG.3.5 Hourly Recirculation Distribution Loss for Central Water Heating Systems).HRDL is zero for all single family water heating systems and for multi-family systems with individual water heaters.

DLM_k = Distribution loss multiplier (unitless).

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system provided in RG.3.1 Hourly Hot Water Consumption (GPH).

T_s = Hot water supply temperature of 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in RG.3.3 Cold Water Inlet Temperature.

$SDLM_k$ = Standard distribution loss multiplier (unitless). This is calculated using Equation RG-5 for single story dwelling units and from Equation RG-6 for dwelling units with two or more stories. All multi-family projects utilize Equation RG-5 and the average dwelling unit CFA.

DSM_k = Distribution system multiplier (unitless) provided in RG.3.2 Distribution System Multiplier (DSM) within the Dwelling Unit.

CFA_k = Conditioned floor area (ft^2) capped at 2500 ft^2 for all single and multi-family units.

When a water heating system has more than one water heater, the total system load is assumed to be shared equally by each water heater. The HARL for the j^{th} water heater is then shown in the following equation.

Equation RG-8

$$HARL_j = \frac{HARL_k}{NmbrWH_k}$$

where

$NmbrWH_k$ = The number of water heaters in the k^{th} system.

RG.3.1 Hourly Hot Water Consumption (GPH)

The average daily hot water consumption GPD for a dwelling unit is equal to 21.5 gallons/day plus an additional 14 gallons per day for each 1000 ft² of conditioned floor area. Consumption is about 31.3 gallons/day for a 700 ft² apartment and 56.5 gallons/day for a 2500 ft² dwelling unit. The equation for daily hot water consumption can be expressed as follows:

Equation RG-9

$$GPD_I = 21.5 + 0.014 \times CFA_I$$

where

GPD_i = Average daily hot water consumption (gallons) of the i^{th} dwelling unit.

CFA_i = Conditioned floor area (ft²) of the i^{th} dwelling unit. When actual conditioned floor area is greater than 2500 ft², 2500 should be used in the above equation.

The hourly water consumption GPH of the k^{th} system is calculated using the average daily hot water consumption and the hourly water consumption schedule for all dwelling units served by the system.

Equation RG-10

$$GPH_k = \left(\sum_i GPD_i\right) \times SCH_m$$

where

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system.

SCH_m = Fractional daily load for hour "m" from Table RG-1.

m = Hour of the day.

There are significant variations between hot water usage on weekdays and weekends, and separate schedules are used. The hourly schedules shown in Table RG-1 shall be used for calculating the hourly hot water consumption. These data are used for dwelling units of all types.

Table RG-1 Hourly Water Heating Schedules

Hour	Weekday	Weekend
1	0.014	0.018
2	0.008	0.010
3	0.009	0.009
4	0.011	0.008
5	0.020	0.015
6	0.044	0.023
7	0.089	0.026
8	0.107	0.047
9	0.089	0.077
10	0.066	0.083
11	0.052	0.074
12	0.038	0.061
13	0.036	0.051
14	0.033	0.043
15	0.032	0.039
16	0.026	0.039
17	0.042	0.052
18	0.048	0.058
19	0.052	0.056
20	0.047	0.052
21	0.042	0.047
22	0.039	0.044
23	0.036	0.040
24	0.022	0.028
Sum	1.000	1.000

RG.3.2 Distribution System Multiplier (DSM) within the Dwelling Unit

The distribution system multiplier (unitless) is an adjustment for alternative water heating distribution systems within the dwelling unit. A value of one is used for standard distribution systems defined as a “main and branch” piping system with the portion of all lines leading from the water heater to the kitchen fixtures that are equal to or greater than ¾ inch diameter insulated to a nominal R-4. Values for alternative distribution systems are given in Table RG-2.

Table RG-2 Distribution System Multipliers within a Dwelling Unit with One or More Water Heaters

Distribution System Measure	Code	DSM
Pipe Insulation (all lines)	PIA	0.90
Point of Use	POU	0.00
Pipe Insulation (kitchen lines = 3/4 inches) – Standard Case	STD	1.00
Standard pipes with no insulation	SNI	1.19
Parallel Piping	PP	1.04
Recirculation (no control)	RNC	4.52
Recirculation + timer control	RTm	3.03
Recirculation + temperature control	RTmp	3.73
Recirculation + timer/temperature	RTmTmp	2.49
Recirculation + demand control	RDmd	1.31

RG.3.2.1 Pipe Insulation Eligibility Requirements

Pipe insulation on the first five feet of hot and cold water piping from storage gas water heaters is a mandatory measure as specified in Section 150 (j) of Title 24, Part 6. Note that exceptions 3, 4 and 5 to Section 150 (j) apply to all pipe insulation that is required to meet the mandatory measure requirement or that is eligible for compliance credit.

Pipe insulation credit available if all remaining hot water lines are insulated. Insulation shall meet mandatory minimums in Section 150 (j).

Overhead Plumbing for Non-Recirculation Systems. All plumbing located in attics with a continuous minimum of 4 in. of blown insulation coverage on top of the piping will be allowed to claim the “all lines” pipe insulation credit, provided that:

1. Piping from the water heater to the attic, and
2. Piping in floor cavities or other building cavities are insulated to the minimum required for pipe insulation credit.

RG.3.2.2 Point of Use Water (POU) Water Heaters Eligibility Requirements

Current requirements apply. All hot water fixtures in the dwelling unit, with the exception of the clothes washer, must be located within 8’ (plan view) of a point of use water heater. To meet this requirement, some houses will require multiple POU units.

RG.3.2.3 Recirculation Systems Eligibility Requirements

All recirculation systems must have minimum nominal R-4 pipe insulation on all supply and return recirculation piping. Recirculation systems may not take an additional credit for pipe insulation.

The recirculation loop must be laid out to be within 8 feet (plan view) of all hot water fixtures in the house (with the exception of the clothes washer).

Approved recirculation controls include “no control”, timer control, time/temperature control, and demand control. Time/temperature control must have an operational timer initially set to operate the pump no more than 16 hours per day. Temperature control must have a temperature sensor with a minimum 20°F deadband installed on the return line.

Demand recirculation systems shall have a pump (maximum 1/8 hp), control system, and a timer or temperature sensor to turn off the pump in a period of less than 2 minutes from pump activation. Acceptable control systems include push buttons, occupancy sensors, or a flow switch at the water heater for pump initiation. At a minimum, push buttons and occupancy sensors must be located in the kitchen and in the master bathroom.

RG.3.2.4 Parallel Piping Eligibility Requirements

Each hot water fixture is individually served by a line, no larger than ½ in., originating from a central manifold located no more than 8 feet from the water heater. Fixtures, such as adjacent bathroom sinks, may be "doubled up" if fixture unit calculations in Table 6-5 of the California Plumbing Code allow.

Acceptable piping materials include copper and cross-linked polyethylene (PEX), depending upon local jurisdictions.

3/8 in. lines are acceptable, pending local code approval, provided minimum required pressures listed in the California Plumbing Code (Section 608.1) can be maintained.

Piping to the kitchen fixtures (dishwasher and sink(s)) that is equal to or greater than ¾ inch in diameter must be insulated to comply with Section 151(f)8D.

RG.3.3 Cold Water Inlet Temperature

The water inlet temperature varies monthly by climate zone and is equal to the assumed ground temperature as shown in Table RG-3.

Table RG-3 Monthly Ground Temperature (ºF)

Climate Zone	Month											
	1	2	3	4	5	6	7	8	9	10	11	12
1	52.2	51.5	51.4	51.8	53.1	54.5	55.6	56.4	56.4	55.8	54.7	53.4
2	53.3	51.5	51.4	52.2	55.6	58.9	61.8	63.6	63.8	62.3	59.5	56.3
3	55.1	54.1	54.0	54.5	56.5	58.5	60.3	61.4	61.5	60.6	58.9	56.9
4	55.5	54.0	53.9	54.6	57.5	60.3	62.8	64.3	64.5	63.2	60.8	58.0
5	55.7	54.8	54.7	55.2	56.9	58.7	60.2	61.1	61.2	60.4	59.0	57.3
6	59.1	58.1	58.0	58.5	60.4	62.4	64.0	65.1	65.2	64.3	62.7	60.8
7	60.1	59.1	59.0	59.5	61.5	63.4	65.2	66.2	66.3	65.5	63.8	61.9
8	60.0	58.8	58.7	59.2	61.6	63.9	66.0	67.3	67.4	66.3	64.3	62.1
9	60.5	59.1	59.0	59.7	62.2	64.8	67.1	68.5	68.6	67.5	65.3	62.8
10	59.4	57.6	57.4	58.3	61.8	65.2	68.2	70.1	70.2	68.7	65.8	62.4
11	54.9	52.4	52.2	53.4	58.2	63.0	67.2	69.8	70.0	67.9	63.8	59.2
12	54.6	52.5	52.3	53.3	57.3	61.3	64.8	67.0	67.2	65.4	62.0	58.1
13	57.5	54.7	54.5	55.8	61.0	66.2	70.6	73.5	73.7	71.4	67.0	62.0
14	54.2	51.2	51.0	52.4	58.2	63.9	68.8	72.0	72.2	69.7	64.8	59.3
15	66.8	64.0	63.8	65.1	70.4	75.8	80.4	83.3	83.6	81.2	76.7	71.5
16	44.4	41.8	41.6	42.8	47.7	52.6	56.8	59.5	59.7	57.5	53.4	48.7

RG.3.4 Solar Savings Multiplier

Solar water heating systems and collectors are rated using infomation from the Solar Rating and Certification Corporation (SRCC). Two types of ratings are possible: those using SRCC OG-300 are for systems, and those using SRRC OG-100 are for collectors that will be used in built-up systems.

RG.3.4.1 Determining Solar Savings Multiplier for SRCC OG-300 Rated Systems

For solar water heating systems rated using SRCC OG-300, the solar savings multiplier SSM_k is calculated as follows:

Equation RG-11

$$SSM_k = 1 - A \times \left(1 - \left(\frac{\left(\frac{EF_{test,k} \times Q_{deltest}}{SEF_{rated,k}} \right) x \left(\frac{GPD_k}{64.3} \right) \times \left(\frac{T_s - T_{inlet}}{77} \right) + 3500 \times SYS_{type,k} \times \left(1 - EF_{test,k}\right)}{Q_{deltest}} \right) \times \left(\frac{1500}{\sum_{hr=1}^{hr=24} I_{hor,hr}} \right) \right)$$

where

$EF_{test,k}$ = Energy Factor used in SRCC OG-300 rating method for auxiliary water heater type used for rating. Two values are possible, 0.90 for a rating with an electric auxiliary water heater and 0.60 for a rating with a gas auxiliary water heater.

$Q_{deltest}$ = The standard OG-300 energy in the hot water delivered, 41,045 Btu/day.

$SEF_{rated,k}$ = The SEF rating as described in SRCC OG-300 and the Summary OG-300 directory for the k^{th} system.

3500 = Average parasitic loss for a Forced Circulation system (Btu/day).

$SYS_{type,k}$ = The OG-300 system type. There are four system types rated in OG-300. Force Circulation, Integral Collector Storage, Thermosyphon, and Self-Pumping. For Forced Circulation type systems this value is set to one. For all others, it is set to zero.

GPH_k = Hourly hot water consumption (gallons) of the k^{th} system.

64.3 = The standard OG-300 water draw of 64.3 gallons per day.

T_s = Hot water supply temperature of 135ºF.

T_{inlet} = The cold water inlet temperature (ºF) provided in Table RG-3.

77 = Difference between Ts and T_{inlet} used in OG-300 test (ºF).

1500 = OG-300 test daily solar insolation (Btu/hr-ft^2).

$I_{hor,hr}$ = Hourly Horizontal solar insolation from weather data for each climate zone (Btu/hr-ft^2).

Hr = Hour of the day from 1 through 24.

A = An adjustment factor to account for piping losses. For Forced Circulation systems A equals 0.9 to account for collector to tank circulation piping heat loss effects. For other systems, A equals 1.0.

Eligibility Criteria

In order to use this method, the system must satisfy the applicable eligibility criteria, including:

- The collectors must face within 35 degrees of south and be tilted at a slope of at least 3:12.
- The system must be installed in the exact configuration for which it was rated, e.g. the system must have the same collectors, pumps, controls, storage tank and auxiliary system fuel type as the rated condition.
- The system must be installed according to manufacturer's instructions.
- The collectors shall be located in a position that is not shaded by adjacent buildings or trees between 9:00 AM and 3:00 PM (solar time) on December 21.

RG.3.4.2 Determining Solar Savings Multiplier for SRCC OG-100 Rated Equipment

Calculating solar hot water system energy contributions requires that the system be modeled using F-chart. Version 4.0 and all later versions can be used to calculate the percent of water heating energy delivered by the solar system. The data listed in Table RG-4 should be followed as inputs for correctly modeling solar hot water systems. If the collector type is not flat plate then the user should refer to the F-chart user manual.

Table RG-4 Prototype Solar System

F-Chart Parameter	***Value***
Collector - Number of	Enter the number of collectors in the system
Collector Area	Enter square feet of the collector listed in the SRCC directory
Collector (test slope) or FR*UL from SRCC data	Enter the value listed in the SRCC directory (I.E. -.272)
Collector (test intercept) or FR*TAU*ALPHA from SRCC data	Enter the value listed in the SRCC directory (I.E. .500 'kepstein@archenergy.com' 7)
Collector Slope	Enter degrees from horizontal
Collector Orientation	Enter orientation as an azimuth, with 0 representing north.
Collector Incident angle modifier calculation	Set to glazing.
Number of glass covers	Enter the number of the layer of transparent covers for the collector.
Collector Flow Rate/Area	Calculate or set to a default of 11 lb/hr-ft2. If calculated, determine the value by dividing the flow rate of the system by the collector area.
Collector Fluid Specific Heat	Set to 1.00 for water, 0.8 for glycol and 0.23 for air. Units in Btu/lb-F.
Collector Modify Test Values	Set to “no.”
System location	Select the climate zone the permitted building is located in.
System water volume/collector ratio	Calculate by dividing the volume of the storage tanks and collectors by the collector area. Does not include piping volume.
System Efficiency of (auxiliary) fuel usage	Set to 1 – this input does not change results.
System Daily hot water usage	Value must be calculated using Equation RG-9.
System water set temperature	Value must be set to 135.
System environmental temperature	Value must be the January value from table RG-3.
System UA of auxiliary storage tank	Calculate using the value determined with Equation RG-33 times 1/R value of the insulation.
System pipe heat loss	Assume value to be 0.
System collector-store heat exchanger	Enter Yes or No.
Tank-side flow-rate/area	Entered in lbs/hr-ft2 is the mass flow rate of water from the storage tank through the collector-storage heat exchanger divided by the total collector area. (Set this to a value larger than the collector flow rate/area in the collector parameters for an internal heat exchanger).
Heat exchanger effectiveness	Enter this ratio of the actual to maximum possible heat transfer rates for the heat exchanger located between the collector and storage unit.

F-chart will generate a Solar Fraction (SF). This value is an annual fraction of the total hot water demand met by the solar system. To adjust the SF to daily loads use Equation RG-12.

Equation RG-12

$$SSM_k = 1 - SF_k \times A$$

where

SF_k = Solar Factor (SF) derived from F-chart.

A = An adjustment factor to account for piping losses. For Forced Circulation systems A equals 0.9 to account for collector to tank circulation piping heat loss effects. For other systems, A equals 1.0.

RG.3.5 Hourly Recirculation Distribution Loss for Central Water Heating Systems

The distribution losses accounted for in the distribution system multiplier DSM are within each individual dwelling unit. Additional distribution losses occur in most multi-family dwelling units related to recirculation systems between dwelling units. These losses include losses from piping that is or could be part of a recirculation loop and branch piping to individual residential units. These losses are divided into losses to the outside air, the ground and the conditioned or semi-conditioned air within the building envelope.

Outside air includes crawl spaces, unconditioned garages, unconditioned equipment rooms, as well as actual outside air. Solar radiation gains are not included in the calculation because the impact of radiation gains is relatively minimal compared to other effects. Additionally, the differences in solar gains for the various conditions (e.g., extra insulation vs. minimum insulation) are relatively even less significant.

The ground condition includes any portion of the distribution piping that is underground, including that in or under a slab. Insulation in contact with the ground must meet all the requirements of Section 150 (j), Part 6, of Title 24.

The losses to conditioned or semi-conditioned air include losses from any distribution system piping that is in an attic space, within walls (interior, exterior or between conditioned and unconditioned spaces), within chases on the interior of the building, or within horizontal spaces between or above conditioned spaces. It does not include the pipes within the residence. The distribution piping stops at the point where it first meets the boundaries of the apartment.

These losses are added to the load accounted for in the hourly adjusted recovery load HARL, according to Equation RG-1 and calculated in the following equation.

Equation RG-13 $$HRDL_k = NL_{OA} \times UA_{OA} \times (T_s - T_{OA}) + NL_{UG} \times UA_{UG} \times (T_s - T_G) + NL_P \times UA_P$$

where

$HRDL_k$ = Hourly recirculation distribution loss (Million Btu).

T_s = Hot water supply temperature of 135°F.

T_{OA} = Hourly dry-bulb temperature of outside air (°F).

T_G = Hourly ground temperature (°F) assumed constant for each month.

NL_{OA} = Normalized load coefficient for outside air term.

NL_{UG} = Normalized load coefficient for underground term.

NL_P = Normalized load coefficient for conditioned or semi-conditioned term.

UA_{OA} = Heat loss rate of circulation pipe exposed to outside air (Btu/hr-°F).

UA_{UG} = Heat loss rate of circulation pipe buried under ground (Btu/hr-°F).

UA_P = Heat loss rate of circulation pipe in conditioned or semi-conditioned space (Btu/hr-°F).

The terms UA_{OA}, UA_{UG}, and UA_P represent the conductive area and heat loss rate for the three pipe locations. In each case the UA is a function of the pipe length, pipe diameter and pipe insulation. The program user will need to specify pipe length in each of the three locations, and specify the insulation as being either minimum (as specified in Section 150 (j), Part 6, of Title 24), or extra. Length and corresponding insulation R-value takeoffs are required for piping in each of the three locations (outdoors, underground, and conditioned or semi-conditioned space). Pipe heat loss rates (UA_{OA}, UA_{UG}, and UA_p) are then calculated for use in Equation RG-13.

The normalized load coefficients, NL_{OA}, NL_{UG}, and $NL_{P,}$ are climate zone specific multipliers for the pipe losses to the outside air, ground and conditioned or semi-conditioned space, respectively. They are calculated according to the following equations:

Equation RG-14 $$NL_{OA} = \frac{C_{OA1} \times \exp\left(\frac{C_{OA2} \times UA_{OA}}{GPD_k}\right)}{WHDH_{OA}}$$

Equation RG-15

$$NL_{UG} = \frac{C_{UG1} \times \exp\left(\frac{C_{UG2} \times UA_{UG}}{GPD_k}\right)}{WHDH_{UG}}$$

Equation RG-16

$$NL_P = \frac{C_{P1} \times \exp\left(\frac{C_{P2} \times UA_P}{GPD_k}\right)}{8760}$$

where

GPD_k = The hot water consumption per day for the k^{th} system. It is the sum of hot water consumption per day for all dwelling units served by the k^{th} system.

$WHDH_{OA}$ = Water heating degree hours based on outside air temperature (hr-°F).

$WHDH_{UG}$ = Water heating degree hours based on ground temperature (hr-°F).

C_{OA1} , C_{OA2} = Coefficients for outside air pipe loss term.

C_{UG1} , C_{UG2} = Coefficients for underground pipe loss term.

C_{P1} , C_{P2} = coefficients for conditioned or semi-conditioned space pipe loss term.

Coefficients of C_{OA}, C_{UG}, and C_P vary by climate zones and control schemes of the circulation system. Table RG-5 lists values of these coefficients.

Table RG-5 Coefficients of C_{OA}, C_{UG} and C_P

Climate Zone	No Controls						Timer Controls					
	COA1	COA2	CUG1	CUG2	CP1	CP2	COA1	COA2	CUG1	CUG2	CP1	CP2
1	0.8933	-0.694	0.8922	-1.346	0.6259	-1.673	0.8658	-2.336	0.793	-2.062	0.6344	-4.475
2	0.854	-0.71	0.8524	-1.348	0.6433	-1.383	0.8269	-2.456	0.7572	-2.056	0.6529	-4.138
3	0.8524	-0.709	0.851	-1.355	0.6826	-1.464	0.8252	-2.37	0.7553	-2.049	0.6927	-4.438
4	0.8349	-0.688	0.8345	-1.343	0.6502	-0.706	0.8096	-2.433	0.7427	-2.071	0.667	-3.759
5	0.8494	-0.706	0.8476	-1.341	0.6873	-1.076	0.8218	-2.409	0.7536	-2.061	0.6922	-3.979
6	0.8095	-0.704	0.808	-1.341	0.7356	-1.697	0.7836	-2.367	0.718	-2.059	0.7341	-4.512
7	0.796	-0.673	0.7964	-1.349	0.735	-1.581	0.7734	-2.395	0.7082	-2.064	0.7416	-4.579
8	0.7941	-0.704	0.7925	-1.341	0.7321	-1.471	0.7683	-2.414	0.7049	-2.064	0.7333	-4.318
9	0.7853	-0.707	0.7843	-1.352	0.7208	-1.212	0.7599	-2.447	0.6971	-2.064	0.7248	-4.141
10	0.7854	-0.714	0.7843	-1.352	0.7193	-1.273	0.7595	-2.5	0.6971	-2.067	0.7188	-4.041
11	0.8137	-0.69	0.8139	-1.35	0.6149	-1.22	0.788	-2.443	0.7228	-2.051	0.6315	-4.306
12	0.8283	-0.685	0.8286	-1.349	0.6001	-0.323	0.8029	-2.451	0.7367	-2.061	0.621	-3.493
13	0.7818	-0.705	0.7813	-1.352	0.6699	-1.541	0.7564	-2.465	0.6937	-2.052	0.6752	-4.305
14	0.8094	-0.706	0.809	-1.351	0.6424	-0.866	0.784	-2.49	0.7187	-2.059	0.6515	-3.588
15	0.6759	-0.692	0.6764	-1.348	0.7514	-1.383	0.6535	-2.552	0.601	-2.061	0.7493	-4.182
16	0.9297	-0.701	0.929	-1.352	0.5231	-1.519	0.9007	-2.401	0.825	-2.053	0.5437	-4.423

Table RG-5 provides coefficients for recirculation systems where the pumps are always on and coefficients for recirculation systems that are shut off during hours 1 through 5, and hours 23 and 24 (from 10p.m. to 5a.m.). Except for systems serving only a very small number of dwelling units, there is no set of coefficients provided for the case where the circulation system does not rely on a recirculation pump. Such a system would be unlikely to supply hot water within parameters acceptable to tenants. It can be assumed that any distribution systems for supplying hot water from a central boiler or water heater require a recirculation pump and one would be supplied retroactively if not initially. For central hot water systems serving six or fewer dwelling units which have (1) less than 25' of distribution piping outdoors; (2) zero distribution piping underground; (3) no recirculation pump; and (4) insulation on distribution piping that meets the requirements of Section 150 (j) of Title 24, Part 6, the distribution system in the Standard Design and Proposed design will both assume a pump with timer controls.

$WHDH_{OA}$ is the sum of the differences between the temperature of the supply hot water (135°F) and the hourly outdoor temperature for all 8760 hours of the year. This term varies by climate zone. The values for this term are listed in Table RG-6 below. The equation uses the hourly outdoor temperatures from the weather files incorporated in the CEC approved programs.

$WHDH_{UG}$ is the sum of the differences between the supply hot water temperature (135°F) and the hourly ground temperature for all 8760 hours of the year. This term varies by climate zone. The appropriate values for this term are listed in Table RG-6 below. The equation uses the ground temperatures from the weather files incorporated in the CEC approved programs, which are assumed to be stable on a monthly basis.

Table RG-6 Water Heating Degree Hours for Outside Air and Underground

Climate Zone	$WHDH_{OA}$ (hr-°F)	$WHDH_{UG}$ (hr-°F)
1	712810	710306
2	680634	678425
3	679350	677026
4	666823	664459
5	677373	674935
6	645603	643236
7	636342	633811
8	633244	630782
9	626251	623822
10	625938	623741
11	649661	647770
12	661719	659676
13	623482	621526
14	645367	643517
15	539736	537782
16	741372	739378

UA terms are calculated using inputs provided by the user and base assumptions about the pipe diameter: The user inputs are:

1. Pipe length in each of the three locations.
2. Insulation R value of the pipe in each location.
3. Number of stories above grade.
4. Number of apartment units.

The total length of the circulation pipe is calculated, along with the fraction in each location (PF_{OA}, PF_{UG} and PF_P). The square feet of surface area is calculated according to the following equation:

Equation RG-17 $$SF_{total} = LF_{total} \times Dia \times \pi$$

where

SF_{Total} = The total surface area of the circulation piping, square feet.

LF_{Total} = The total lineal feet of all circulation piping, feet. Dia = Average calculated (Equation RG-18) diameter of pipe in circulation piping, feet.

π = Pythagorean constant (ratio of perimeter to diameter), 3.1416

The average diameter of hot water piping, Dia, is calculated by the following equation:

Equation RG-18 $$Dia = 0.045 \times \left(\frac{LF_{Total}}{\Delta P}\right)^{0.21} \times (AptGPM)^{0.37} \times \frac{(NumApts)^{0.37}}{1.37}$$

The terms of the above equation are described below. The total system pressure drop, ΔP, given in psf is calculated in Equation RG-19.

Equation RG-19 $$\Delta P = \left[P_{meter} - 4.3 \times (NumStories - 1) - 15\right] \times 144$$

where

P_{meter} = Water system supply pressure, (60 psig by assumption).

NumStories = Number of stories above grade, (but enter “4” if more than 4 stories).

Equation RG-20 $$AptGPM = \frac{1.765 \times (12 \times NumApts)^{0.687}}{NumApts}$$

NumApts = Number of apartments in the building served by the hot water system, apts

The UA for each of the three locations is derived as a function of the fraction of the total pipe in that location times a factor that represents the conductivity of the standard (minimum) insulation or the “extra” insulation condition. The following two equations provide the alternate equations for the two insulation cases. The factors do not vary by location so the equations for the other two locations are of exactly the same form, varying only by the fraction of pipe in that location.

The benefits of additional insulation shall be calculated as required in Section 150 (j) of Title 24. The insulation value of the ground and of protective coverings may not be used for achieving the minimum insulation values required by Section 150 (j). To qualify as extra insulation, the insulation must be at least 1/2" thicker than the insulation required by Section 150 (j).

Equation RG-21 For extra insulation for the standard design: $$UA_i = SF_{Total} \times PF_i \times \left(\frac{k}{Radius \times Ln\left(\frac{Radius + Thick + 0.5}{Radius}\right)}\right)$$

Equation RG-22 For minimum insulation: $$UA_i = SF_{Total} \times PF_i \times \left(\frac{k}{Radius \times Ln\left(\frac{Radius + Thick}{Radius}\right)}\right)$$

where

i = Subscript indicating pipe location OA = outside, UG = underground, P = conditioned or semi-conditioned space

PF_i = Pipe fraction in i^{th} location, no units

k = Insulation conductivity, (assumed 0.25 Btu inch/h·sf·°F)

Radius = Average pipe radius in inches, (Radius = Dia x 12 / 2), inches

Thick = Base case insulation thickness, Thick = 1 if average pipe radius is less than or equal to 2";Thick = 1.5 if radius is greater than 2", inches

RG.4 Energy Use of Individual Water Heaters

Once the hourly adjusted recovery load is determined for each water heater, the energy use for each water heater is calculated as described below.

RG.4.1 Small[1] Gas, Oil, or Electric Storage and Heat Pump Water Heaters

The hourly energy use of storage gas, storage electric and heat pump water heaters is given by the following equation.

Equation RG-23
$$WHEU_j = \left[\frac{HARL_j \times HPAF_j}{LDEF_j}\right] WSAF_j$$

where

$WHEU_j$ = Hourly energy use of the water heater (Btu for fuel or kWh for electric), adjusted for tank insulation and wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load (Btu).

$HPAF_j$ = Heat pump adjustment factor from the table below based on climate zone. This value is one for storage gas, storage oil and storage electric water heaters.

The energy consumption of one or more independent hot water storage tanks that are not rated as water heaters is calculated by substituting $xHARL_j$ for $HARL_j$ where $xHARL_j$ is defined in Section __.

Table RG-7 Heat Pump Adjustment Factors

Climate Zone	Heat Pump Adjustment Factor	Climate Zone	Heat Pump Adjustment Factor
1	1.040	9	0.920
2	0.990	10	0.920
3	0.990	11	0.920
4	1.070	12	1.070
5	1.070	13	0.920
6	0.920	14	1.040
7	0.920	15	0.920
8	0.920	16	1.500

$LDEF_j$ = The hourly load dependent energy factor (LDEF) is given by the following equation. This equation adjusts the standard EF for different load conditions.

Equation RG-24
$$LDEF_j = e \times \left(\ln\left(\frac{HARL_j \times 24}{1000}\right)\left(a \times EF_j + b\right) + \left(c \times EF_j + d\right)\right)$$

where

a,b,c,d,e = Coefficients from the table below based on the water heater type.

[1] "Small water heater" means a water heater that is a gas storage water heater with an input of 75,000 Btu per hour or less, an oil storage water heater with an input of 105,000 Btu per hour or less, an electric storage water heater with an input of 12 kW or less, a gas instantaneous water heater with an input of 200,000 Btu per hour or less, an oil instantaneous water heater with an input of 210,000 Btu 1602 per hour or less, an electric instantaneous water heater with an input of 12 kW or less, or a heat pump water heater rated at 24 amps or less.

Table RG-8 LDEF Coefficients

Coefficient	Storage Gas	Storage Electric	Heat Pump
a	-0.098311	-0.91263	0.44189
b	0.240182	0.94278	-0.28361
c	1.356491	4.31687	-0.71673
d	-0.872446	-3.42732	1.13480
e	0.946	0.976	0.947

Note: EF for storage gas water heaters under 20 gallons must be assumed to be 0.58 unless the manufacturer has voluntarily reported an actual EF to the California Energy Commission. As of April 2003, manufacturers of this equipment are no longer required to do so.

EFj = Energy factor of the water heater (unitless). This is based on the DOE test procedure.

WSAFj = Wood stove boiler adjustment factor for the j^{th} water heating system. This is given in Section RG.4.6 Wood Stove Adjustment Factors. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG.4.2 Small Gas or Oil Instantaneous[2]

The hourly energy use for instantaneous gas or oil water heaters is given by the following equations.

Equation RG-25

$$WHEU_j = \left(\frac{HARL_j}{EF_j} + PILOT_j\right) \times WSAF_j$$

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from the DOE test procedure (unitless). This is taken from manufacturers literature or from the CEC Appliance Database.

$PILOT_j$ = Energy consumption of the pilot light (Btu/h). Default if no information provided in manufacturer's literature or CEC Appliance Database is 500 Btu/hr.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG.4.3 Small Electric Instantaneous

The hourly energy use for instantaneous electric water heaters is given by the following equation.

Equation RG-26

$$WHEU_{j,elec} = \frac{HARL_j \times WSAF_j}{3413 \times EF_j}$$

where

$WHEU_{j,\,elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

EF_j = Energy factor from DOE test procedure (unitless).

2 "Instantaneous water heater" means a water heater that has an input rating of at least 4,000 Btu per hour per gallon of stored water.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG.4.4 Large[3] Gas or Oil Storage. Large Instantaneous, Indirect Gas and Hot Water Supply Boilers[4].

Energy use for large storage gas and indirect gas water heaters is given by the following equations. Note: large storage gas water heaters are defined as any gas storage water heater with a minimum input rate of 75,000 Btu/h.

Equation RG-27

$$WHEU_j = \left[\frac{HARL_j + HJL_j}{EFF_j \times EAF_j} + PILOT_j\right] \times WSAF_j$$

where

$WHEU_j$ = Hourly fuel energy use of the water heater (Btu), adjusted for tank insulation and wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load. For independent hot water storage tank(s) substitute $xHARL_j$ from Section RG.4.9 Independent Hot Water Storage Tanks for $HARL_j$.

HJL_j = Hourly jacket loss (Btu/h) for tank rated with the water heater. For nonstorage water heaters and boilers set this term to zero. To account for independent hot water storage tanks substitute $xHARL_j$ (from Section RG.4.9 Independent Hot Water Storage Tanks) for $HARL_j$ storage tanks

EFF_j = Efficiency (fraction, not %). To be taken from CEC Appliance Database or from manufacturers literature. These products may be rated as a recovery efficiency, thermal efficiency or AFUE.

EAF_j = Efficiency adjustment factor (unitless). This value is 1.0 for large storage gas water heaters and 0.98 for indirect gas water heaters.

$PILOT_j$ = Pilot light energy (Btu/h) for large instantaneous. For large instantaneous water heaters, and hot water supply boilers the default is 750 Btu/hr if no information is provided in manufacturer's literature or CEC Appliance Database. For storage type water heaters the default is zero.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG.4.5 Large Electric Storage

Energy use for large storage electric water heaters is given by the following equation.

Equation RG-28

$$WHEU_{j,elec} = \left[\frac{HARL_j + HJL_j}{0.85 \times 3.413}\right] \times WSAF_J$$

where

$WHEU_{j,\ elec}$ = Hourly electricity energy use of the water heater (kWh), adjusted for wood stove boilers.

$HARL_j$ = Hourly adjusted recovery load.

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3 "Large water heater" means a water heater that is not a small water heater.

4 "Hot water supply boiler" means an appliance for supplying hot water for purposes other than space heating or pool heating.

HJL_j = Hourly jacket loss (Btu/h) for the tank rated with the heater.

$WSAF_j$ = Wood stove boiler adjustment factor for the j^{th} water heating system. This is an optional capability and is set to 1.00 for ACMs without wood stove boiler modeling capability.

RG.4.6 Wood Stove Adjustment Factors

This is an optional capability and the Wood Stove Boiler Adjustment Factor is set to 1.00 for ACMs without wood stove boiler modeling capability. The wood stove adjustment factor (unitless) reduces water heating energy to account for the heat contribution of wood stove boilers. This multiplier is taken from the table below, based on climate zone and whether the wood stove boiler has a recirculation pump. The inclusion of this factor and its relevant input parameters is an optional capability for ACMs. However, when this optional capability is implemented the algorithms and procedures given below must be used.

Table RG-9 Wood Stove Adjustment Factors

Climate Zone	Wood Stoves with Pumps	Wood Stoves without Pumps
1	0.775	0.750
2	0.775	0.750
3	0.775	0.750
4	0.865	0.850
5	0.865	0.850
6	0.910	0.900
7	0.910	0.900
8	0.955	0.950
9	0.910	0.900
10	0.955	0.950
11	0.910	0.900
12	0.865	0.850
13	0.910	0.900
14	0.910	0.900
15	1.000	1.000
16	0.730	0.700

RG.4.7 Jacket Loss

The hourly jacket loss for large storage gas and indirect gas water heaters is calculated as

Equation RG-29

$$HJL_J = \frac{TSA_j \times \Delta TS}{RTI_j + REI_j} + FTL_j$$

where

TSA_j = Tank surface area (ft^2).

FTL_j = Fitting losses. This is a constant 61.4 Btu/h.

REI_j = R-value of exterior insulating wrap.

RTI_j = Calculated R-value of insulation internal to water heater.

For water heaters with standby loss rated in percent heat content of the stored water:

Equation RG-30
$$RTI_j = \frac{TSA_j \times \Delta TS}{\left[\left(8.345 \times VOL_j \times SBL_j \times \Delta T\right) - FTL_j - PILOT_j\right] \times EFF_j \times EAF_j}$$

For water heaters with standby loss rated in Btu/hr:

Equation RG-31
$$RTI_j = \frac{TSA_j \times \Delta TS}{\left[\left(SBE_j \times \left(\frac{\Delta TS}{60}\right)\right) - FTL_j - PILOT_j\right] \times EFF_j \times EAF_j}$$

SBE_j = Standby loss expressed in Btu/hr from the CEC Appliance Database or from manufacturer's literature.

SBL_j = Standby loss expressed as a fraction of the heat content of the stored water lost per hour from the CEC Appliance Database or from manufacturer's literature.

$PILOT_j$ = Pilot light energy (Btu/h). If no information is provided in manufacturer's literature or CEC Appliance Database default to zero.

ΔTS = Temperature difference between ambient surrounding water heater and hot water supply temperature (ºF). Hot water supply temperature shall be 135ºF. For water heaters located inside conditioned space use 75ºF for the ambient temperature. For water heaters located in outside conditions use hourly dry bulb temperature ambient.

The hourly jacket loss for large storage electric heaters is calculated as:

Equation RG-32
$$HJLi = \frac{TSA \times \Delta T}{\left(RTIj + REIj\right)}$$

(same definitions as above)

RTIj = Calculated R-value of insulation internal to water heater.

REIj = R-value of exterior insulating wrap.

Where the calculated insulation R-value RTI_j is calculated by:

Equation RG33
$$RTIj = \frac{\left(TSAj \times \Delta TS\right)}{\left[\left(8.345 \times VOL_j \times SBLj \times \Delta TS\right) \times EFFj\right]}$$

where

SBLj = Standby loss expressed in percent heat content loss of the stored water, from manufacturer's data.

EFFj = Efficiency, from manufacturer's data.

RG.4.8 Tank Surface Area

Tank surface area (TSA) is used to calculate the hourly jacket loss (HJL) for large storage gas, indirect gas water heaters, and large storage electric water heaters. TSA is given in the following equation as a function of the tank volume.

Equation RG-34
$$TSA_j = e \times \left(f \times VOL_j^{0.33} + g\right)^2$$

where

VOL_j = Tank capacity (gallons).

e, f, g = Coefficients given in the following table.

Table RG-10 Coefficients for Calculating Tank Surface Areas

Coefficient	Storage Gas	Large Storage Gas and Indirect Gas	Storage Electric and Heat Pumps
E	0.00793	0.01130	0.01010
F	15.67	11.8	11.8
G	1.9	5.0	5.0

RG.4.9 Independent Hot Water Storage Tanks

The additional loads due to independent hot water storage tanks which are not rated as water heaters is calculated by adding the sum of the jacket losses for one or more of these tanks to the Hourly Adjusted Recovery Load for the jth water heater and substituting $xHARL_j$ for $HARL_j$ in the appropriate equation above for the jth water heater:

Equation RG-35

$$xHARL_j = HARL_j + \sum_k HJL_{j,k}$$

where

$xHARL_j$ = Hourly Adjusted Recovery Load for the jth water heater plus the load due to independent hot water storage tanks serving the jth hot water heater.

$HARL_j$ = Hourly Adjusted Recovery Load for the jth water heater as defined by Equation RG-1.

$HJL_{j,k}$ = Hourly Jacket Loss of the kth independent hot water storage tank serving the jth water heater.

The hourly jacket loss, HJL is calculated per RG.4.7 Jacket Loss using Equation RG-29. When the Standby Loss for the tank is not available or not listed, RTIj may be set at zero and the total tank insulation may be entered for REI. The minimum value of REI allowed by the ACM shall be a 0.68 still air film.

RG.5 Electricity Use for Circulation Pumping

For single-family recirculation systems, hourly pumping energy is fixed as shown in following table.

Table RG-11 Single Family Recirculation Energy Use (kWh) by Hour of Day

Hour	Uncontrolled Recirculation	Timer Control	Temperature Control	Timer/Temp Control	Demand Recirculation
1	0.040	0	0.0061	0	0.0010
2	0.040	0	0.0061	0	0.0005
3	0.040	0	0.0061	0	0.0006
4	0.040	0	0.0061	0	0.0006
5	0.040	0	0.0061	0	0.0012
6	0.040	0	0.0061	0	0.0024
7	0.040	0.040	0.0061	0.0061	0.0045
8	0.040	0.040	0.0061	0.0061	0.0057
9	0.040	0.040	0.0061	0.0061	0.0054
10	0.040	0.040	0.0061	0.0061	0.0045
11	0.040	0.040	0.0061	0.0061	0.0037
12	0.040	0.040	0.0061	0.0061	0.0028
13	0.040	0.040	0.0061	0.0061	0.0025
14	0.040	0.040	0.0061	0.0061	0.0023
15	0.040	0.040	0.0061	0.0061	0.0021
16	0.040	0.040	0.0061	0.0061	0.0019
17	0.040	0.040	0.0061	0.0061	0.0028
18	0.040	0.040	0.0061	0.0061	0.0032
19	0.040	0.040	0.0061	0.0061	0.0033
20	0.040	0.040	0.0061	0.0061	0.0031
21	0.040	0.040	0.0061	0.0061	0.0027
22	0.040	0.040	0.0061	0.0061	0.0025
23	0.040	0	0.0061	0	0.0023
24	0.040	0	0.0061	0	0.0015
Annual Total	350	234	53	35	23

Multi-family recirculation systems may have vastly different pump sizes and is therefore calculated based on the installed pump size. The hourly electricity use for pumping (HEUP) water in the circulation loop can be calculated by the hourly pumping schedule and the power of the pump motor as in the following equation.

Equation RG-36

$$HEUP_k = \frac{0.746 \times PUMP_k \times SCH_{k,m,}}{\eta_k}$$

where

$HEUP_k$ = Hourly electricity use for the circulation pump (kWh).

$PUMP_k$ = Pump brake horsepower (bhp).

$?_k$ = Pump motor efficiency.

$SCH_{k,m}$ = Operating schedule of the circulation pump. For 24-hour operation (no controls), the value is always 1. For timer controls, the value is 1 when pump is on and 0 otherwise. The pump is assumed off from 10 p.m. to 5 a.m. and on for the remaining hours.

ACM RESIDENTIAL MANUAL APPENDIX RH-2005

Appendix RH – High Quality Insulation Installation Procedures

RH.1 Purpose and Scope

ACM RH-2005 is a procedure for verifying the quality of insulation installation in low-rise residential buildings. A compliance credit is offered when this procedure is followed by the insulation installer and a qualified HERS rater. The procedure and credit applies to wood framed construction with wall stud cavities, ceilings, and roof assemblies insulated with mineral fiber or cellulose insulation in low-rise residential buildings.

RH.2 Terminology

Air Barrier An air barrier is needed in all thermal envelope assemblies to prevent air movement. Insulation, other than foam, is not designed to stop air movement. For insulation installed horizontally, such as in an attic, the insulation must be in substantial contact with the assembly air barrier (usually the ceiling drywall) on one side for it to perform at its rated R-value. A wall or ceiling covering that has multiple leakage sites (such as 1 x 6 toung and grove board ceilings) can not serve as an air barrier.

Air-tight Thermal envelope assemblies (such as wall assemblies) shall be built to minimize air movement. Air movement can move unwanted heat and moisture through or into the assembly. For these procedures air-tight shall be defined as an assembly or air barrier with all openings greater than 1/8 inch caulked, or sealed with expansive or minimally expansive foam.

Excessive Compression Batt insulation may be compressed up to 50% at obstructions such as plumbing vents and in non-standard cavities, but compression of more than 50% in any dimension is excessive and shall not be allowed. Where obstructions would cause the insulation to be compressed greater than 50% insulation shall be cut to fit around the obstruction.

Delaminated Batts are often split or delaminated to fit around an obstruction. For example when an electrical wire runs through a wall cavity the insulation must still fill the area both in front of the wire and the area behind the wire. This is typically accomplished by delaminating the batt from one end and placing one side of the batt behind the wire and the other in front of the wire. The location of the delamination must coincide with the location of the obstruction. For example if the wire is one third of the distance from the front of the cavity the batt should be delaminated so that two thirds of the batt goes behind the wire and one third in front of the wire.

Draft Stops Draft stops are installed to prevent air movement between wall cavities, other interstitial cavities - and the attic. They are typically constructed of dimensional lumber blocking, drywall or plywood. Draft stops become part of the attic air barrier and shall be air-tight. Fire blocks constructed of porous insulation materials cannot serve as draft stops since they are not air-tight.

Friction Fit Friction fit batts are commonly used. Friction fit batts have enough side-to-side frictional force to hold the batt in place without any other means of attachment.

Gaps A gap is an uninsulated area at the edge of or between batts. Gaps in insulation are avoidable and are not permitted.

Hard Covers Hard covers shall be installed above areas where there is a drop ceiling. For example a home with 10 ft ceilings may have an entry closet with a ceiling lowered to 8 ft. A hard cover (usually a piece of plywood) is installed at the 10 ft. level above the entry closet. Hard covers become part of the ceiling air barrier and shall be air-tight.

Inset Stapling In windy areas installers often staple the flanges of faced batts to the sides of the stud in order to assure that the insulation remains in place until covered with drywall, particularly on the wall between the house and the garage where there isn't any exterior sheathing to help keep the insulation in place. The void created by the flange inset shall not extend more than two inches from the stud on each side.

Net Free-Area The net free-area of a vent cover is equal to the total vent opening less the interference to air flow caused by the screen or louver. Screened or louvered vent opening covers are typically marked by the manufacturer with the "net free-area." For example a 22.5 in. by 3.5 in. eave vent screen with a total area of 78.75 square inches may have a net free-area of only 45 square inches.

Voids When batt insulation is pushed too far into a wall stud cavity a void is created between the front of the batt and the drywall. Batts shall be fully lofted and fill the cavity front-to-back. Small voids less than ¾ in. deep on the front or back of a batt shall be allowed as long as the total void area is not over 10% of the batt surface area. This definition shall not preclude the practice of inset stapling as long as the void created by the flange inset meets the specification in the definition of inset stapling. Improper spraying or blowing of insulation in ceilings and wall cavities can result in areas with insufficient insulation not meeting the specified installed density and R-value. Wall and cathedral ceiling cavity areas where cellulose insulation has fallen away shall be filled with insulation. Depressions in netting or material supporting blown insulation in walls and cathedral ceilings shall be filled with insulation.

RH.3 Raised Floors and Floors Over Garages

- Batts shall be correctly sized to fit snugly at the sides and ends, but not be so large as to buckle.
- Batts shall be cut to fit properly without gaps. Insulation shall not be doubled-over or compressed.
- Insulation shall be in contact with an air barrier - usually the subfloor.
- On floors that are over garages, or where there is an air space between the insulation and the subfloor, the rim joist shall be insulated.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- If the insulation is faced, the facing shall be placed toward the living space and be in contact with the underside of the floor sheathing. Continuous support shall be provided to keep the facing in contact with the floor sheathing. Filling the entire cavity with insulation and providing support with netting at the bottom of the framing is one acceptable method.
- Insulation shall be properly supported to avoid gaps, voids, and compression.

RH.4 Wall Insulation

RH.4.1. Batt Installation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate.
- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- The batt shall be friction fitted into the cavity unless another support method is used

- Batt insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Batts with flanges that are inset stapled to the side of the stud must be flush with the face of the cavity (or protrude beyond) except for the portion that is less than two inches from the edge of the stud.
- Non-standard-width cavities shall be filled with batt insulation snuggly fitted into the space without excessive compression.
- Batt insulation shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.

RH.4.2 Narrow-Framed Cavities

- Non-standard width cavities shall be filled by batt insulation cut to snuggly fit into the space.
- Narrow spaces (two inches or less) at windows, between studs at the building's corners, and at the intersections of partition walls shall be filled with batt insulation snuggly fitted into the space (without excessive compression), loose fill insulation, or expansive or minimally expansive foam.

RH.4.3 Special Situations

RH.4.3.1 Installations Prior to Exterior Sheathing or Lath

- Hard to access wall stud cavities such as; corner channels, wall intersections, and behind tub/shower enclosures shall be insulated to the proper R-value. This may have to be done prior to the installation of the exterior sheathing or the stucco lath.

RH.4.3.2 Obstructions

- Insulation shall be cut to fit around wiring and plumbing without compression.
- Insulation shall be placed between the sheathing and the rear of electrical boxes and phone boxes.
- In cold climates, where water pipes may freeze (Climate Zones 14 and 16) pipes shall have at least two-thirds of the insulation between the water pipe and the outside. If the pipe is near the outside, as much insulation as possible shall be placed between the pipe and the outside (without excessive compression), and no insulation shall be placed between the pipe and the inside.

RH.4.3.3 Rim Joists

- All rim-joists shall be insulated to the same R-Value as the adjacent walls.
- The insulation shall be installed without gaps or excessive compression.

RH.4.3.4 Kneewalls and Skylight Shafts

- All kneewalls and skylight shafts shall be insulated to a minimum of R-19.
- The insulation shall be installed without gaps and with minimal compression.
- For steel-framed kneewalls and skylight shafts, external surfaces of steel studs shall be covered with batts or rigid foam unless otherwise specified on the CF-1R using correct U-factors from Joint Appendix IV, Table IV-11 (or U-factors approved by the CEC Executive Director).
- The house side of the insulation shall be in contact with the drywall or other wall finish.
- The insulation shall be supported so that it will not fall down by either fitting to the framing, stapling in place with minimal compression, or using other support such as netting.

RH.4.3.5 HVAC/Plumbing Closet

- Walls of interior closets for HVAC and/or water heating equipment, that require combustion air venting, shall be insulated to the same R-value as the exterior walls.

RH.4.3.6 Loose Fill Wall Insulation

- Wall stud cavities shall be caulked or foamed to provide a substantially air-tight envelope to the outdoors, attic, garage and crawl space. Special attention shall be paid to plumbing and wiring penetrations through the top plates, electrical boxes that penetrate the sheathing, and the sheathing seal to the bottom plate.
- Installation shall uniformly fill the cavity side-to-side, top-to-bottom, and front-to-back.
- Loose fill insulation shall be installed to fill the cavity and be in contact with the sheathing on the back and the wallboard on the front - no gaps or voids.
- Loose fill wall insulation shall be installed to fit around wiring, plumbing, and other obstructions.
- The installer shall certify on forms CF-6R and IC-1 that the manufacturer's minimum weight-per-square-foot requirement has been met.

RH.5 Ceiling and Roof Insulation

RH.5.1 Batt Insulation

RH.5.1.1 General Requirements

- Batts shall be correctly sized to fit snugly at the sides and ends.
- Batts shall be installed so that they will be in contact with the air barrier.
- Where necessary, batts shall be cut to fit properly - there shall be no gaps, nor shall the insulation be doubled-over or compressed.
- When batts are cut to fit a non-standard cavity, they shall be snuggly fitted to fill the cavity without excessive compression.
- Batts shall be cut to butt-fit around wiring and plumbing, or be split (delaminated) so that one layer can fit behind the wiring or plumbing, and one layer fit in front.
- For batts that are taller than the trusses, full-width batts shall be used so that they expand to touch each other over the trusses.
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is installed.
- Required eave ventilation shall not be obstructed - the net free-ventilation area of the eave vent shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the batt.
- Insulation shall cover all recessed lighting fixtures. If the fixtures are not rated for insulation contact (IC) and air tight, the fixtures shall either be replaced or eliminated.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight (AT) rated and shall be sealed with a gasket or caulk between the housing and the ceiling.

RH.5.1.2 Special Situations

RH.5.1.2.1 Rafter Ceilings

- An air space shall be maintained between the insulation and roof sheathing if required by California Building Code section 1505.3.
- Facings and insulation shall be kept away from combustion appliance flues in accordance with flue manufacturers' installation instructions or labels on the flue.

RH.5.1.2.2 HVAC Platform

- Appropriate batt insulation shall be placed below any plywood platform or cat-walks for HVAC equipment installation and access
- Batts shall be installed so that they will be in contact with the air barrier.

RH.5.1.2.3 Attic Access

- Permanently attach rigid foam or a batt of insulation to the access door using adhesive or mechanical fastener.

RH.5.2. Loose-Fill Ceiling Insulation

RH.5.2.1 General Requirements

- Baffles shall be placed at eaves or soffit vents to keep insulation from blocking eave ventilation. The required net free-ventilation shall be maintained.
- Eave vent baffles shall be installed to prevent air movement under or into the loose-fill insulation
- Hard covers or draft stops shall be placed over all drop ceiling areas and interior wall cavities to keep insulation in place and stop air movement. If hard covers or draft stops are missing or incomplete, they shall be completed before insulation is completed or the entire drop area shall be filled with loose-fill insulation level with the rest of the attic.
- Attic rulers appropriate to the material installed shall be evenly distributed throughout the attic to verify depth: one ruler for every 250 square feet and clearly readable from the attic access. The rulers shall be scaled to read inches of insulation and the R-value installed.
- Insulation shall be applied underneath and on both sides of obstructions such as cross-bracing and wiring.
- Insulation shall be applied all the way to the outer edge of the wall top plate.
- Insulation shall cover recessed lighting fixtures. If the fixtures are not rated for insulation contact (IC) and air tight, the fixtures shall either be replaced or eliminated.
- All recessed light fixtures that penetrate the ceiling shall be IC and air tight (AT) rated and shall be sealed with a gasket or caulk between the housing and the ceiling.
- Insulation shall be kept away from combustion appliance flues in accordance with flue manufacturer's installation instructions or labels on the flue.
- Insulation shall be blown to a uniform thickness throughout the attic with all areas meeting or exceeding the insulation manufacturer's minimum requirements for depth and weight-per-square-foot.
- The installer shall certify on forms CF-6R and IC-1 that the manufacturer's minimum weight-per-square-foot requirement has been met.
- The HERS rater shall verify that the manufacturer's minimum weight-per-square-foot requirement has been met for attics insulated with loose-fill mineral-fiber insulation. Verification shall be determined using the methods of the Insulation Contractor's Association of America (ICAA) Technical Bulletin #17 except that only one sample shall be taken in the area that appears to have the least amount of insulation. The rater shall record the weight-per-square-foot of the sample on the CF-4R.
- The HERS rater shall verify that the manufacturer's minimum insulation thickness has been installed. For cellulose insulation this verification shall take into account the time that has elapsed since the insulation was installed. At the time of installation, the insulation shall be greater than or equal to the manufacturer's minimum initial insulation thickness. If the HERS rater does not verify the insulation thickness at the time of installation, and if the insulation has been in place less than seven days, the insulation thickness shall be greater than the manufacturer's minimum required thickness at the time of installation less 1/2 inch to account for settling. If the insulation has been in place for seven days or longer, the insulation thickness shall be greater than or equal to the manufacturer's minimum required settled thickness.

RH.5.2.2 Special Situations

RH.5.2.2.1 Kneewalls and Skylight Shafts:

- Kneewalls and skylight shafts shall be insulated to a minimum of R-19. If loose fill insulation is used it shall be properly supported with netting or other support material.

RH.5.2.2.2 HVAC Platform

- Pressure-fill the areas under any plywood platform or walks for HVAC equipment installation and access or verify that appropriate batt insulation has been installed.

RH.5.2.2.3 Attic Access

- Permanently attach rigid foam or a batt of insulation to the access door using adhesive or mechanical fastener.

RH.6 Materials

- Materials shall comply with Uniform Building Code (including, but not limited to, 1997 UBC Section 707) and installed to meet all applicable fire codes.
- Materials shall meet California Quality Standards for Insulating Material, Title 24, Chapter 4, Article 3, listed in the California Department of Consumer Affairs Consumer Guide and Directory of Certified Insulating Materials.
- Materials shall comply with flame spread rating and smoke density requirements of Sections 2602 and 707 of the Title 24, Part 2: all installations with exposed facings must use fire retardant facings which have been tested and certified not to exceed a flame spread of 25 and a smoke development rating of 450. Insulation facings that do not touch a ceiling, wall, or floor surface, and faced batts on the undersides of roofs with an air space between the ceiling and facing are considered exposed applications.
- Materials shall be installed according to manufacturer specifications and instructions.

RH.7 Equipment

- Scales - The scales used to weigh density samples shall be accurate to within +/- 0.03 pounds. Scales shall be calibrated in accordance with manufacture's instructions.

RH.8 R-Value and U-Value Specifications

See CF-1R for minimum R-value requirements; for non-standard assemblies, also see applicable form 3R.

RH.9 Certificates

An Insulation Certificate (IC-1) signed by the insulation installer shall be provided that states that the installation is consistent with the plans and specifications for which the building permit was issued. The certificate shall also state the installing company name, insulation manufacturer's name and material identification, the installed R-value, and, in applications of loose-fill insulation, the minimum installed weight-per-square-foot (or the minimum weight per cubic foot) consistent with the manufacturer's labeled installed-design-density for the desired R-Value, and the number of inches required to achieve the desired R-Value. The insulation installer shall also complete a form CF-6R and attach a bag label or a manufacturer's coverage chart for every insulation material used.

RH.10 Certificate Availability

The Insulation Certificate (IC-1) and Installation Certificate (CF-6R, with insulation material bag labels or coverage charts attached), signed by the insulation installer, shall be available on the building site for each of the HERS rater's verification inspections. Note: The HERS rater cannot verify compliance credit without these completed forms.

CF-6R & CF-4R Insulation Installation Quality Certificate

Site Address____ Permit __________

- [ ] Installation meets all applicable requirements as specified in the Insulation Installation Procedures

(CF-6R only)

- [ ] Insulation certificate, (IC-1) signed by the installer stating: insulation manufacturer's name, material identification, installed R-values, and for loose-fill insulation: minimum weight per square foot and minimum inches
- [ ] Installation Certificate, (CF-6R) signed by the installer certifying that the installation meets all applicable requirements as specified in the Insulation Installation Procedures

(CF-4R only)

1. FLOOR

- [ ] All floor joist cavity insulation installed to uniformly fit the cavity side-to-side and end-to-end
- [ ] Insulation in contact with the subfloor or rim joists insulated
- [ ] Insulation properly supported to avoid gaps, voids, and compression

2. WALLS

- [ ] Wall stud cavities caulked or foamed to provide an air tight envelope
- [ ] Wall stud cavity insulation uniformly fills the cavity side-to-side, top-to-bottom, and front-to-back
- [ ] No gaps
- [ ] No voids over 3/4" deep or more than 10% of the batt surface area.
- [ ] Hard to access wall stud cavities such as; corner channels, wall intersections, and behind tub/shower enclosures insulated to proper R-Value
- [ ] Small spaces filled
- [ ] Rim-joists insulated
- [ ] Loose fill wall insulation meets or exceeds manufacturer's minimum weight-per-square-foot requirement. (CF-6R only)

3. ROOF/CEILING PREPARATION

- [ ] All draft stops in place to form a continuous ceiling and wall air barrier
- [ ] All drops covered with hard covers
- [ ] All draft stops and hard covers caulked or foamed to provide an air tight envelope
- [ ] All recessed light fixtures IC and air tight (AT) rated and sealed with a gasket or caulk between the housing and the ceiling
- [ ] Floor cavities on multiple-story buildings have air tight draft stops to all adjoining attics
- [ ] Eave vents prepared for blown insulation - maintain net free-ventilation area

☐ Kneewalls insulated or prepared for blown insulation

☐ Area under equipment platforms and cat-walks insulated or accessible for blown insulation

☐ Attic rulers installed

4. ROOF/CEILING BATTS

☐ No gaps

☐ No voids over ¾ in. deep or more than 10% of the batt surface area.

☐ Insulation in contact with the air-barrier

☐ Recessed light fixtures covered

☐ Net free-ventilation area maintained at eave vents

5. ROOF/CEILING LOOSE-FILL

☐ Insulation uniformly covers the entire ceiling (or roof) area from the outside of all exterior walls.

☐ Baffles installed at eaves vents or soffit vents - maintain net free-ventilation area of eave vent

☐ Attic access insulated

☐ Recessed light fixtures covered

☐ Insulation at proper depth – insulation rulers visible and indicating proper depth and R-value

☐ Loose-fill insulation meets or exceeds manufacturer's minimum weight and thickness requirements for the target R-value. Target R-value _________________ Manufacturer's minimum required weight for the target R-value __________________ (pounds-per-square-foot). Manufacturer's minimum required thickness at time of installation ______________ Manufacturer's minimum required settled thickness ______________ Note: In order to receive compliance credit the HERS rater shall verify that the manufacturer's minimum weight and thickness has been achieved for the target R-value. (CF-6R only)

☐ Loose-fill mineral fiber insulation meets or exceeds manufacturer's minimum weight and thickness requirement for the target R-value. Target R-value _____________________ Manufacturer's minimum required weight for the target R-value ______________________ (pounds-per-square foot). Sample weight _____________________ (pounds per square foot). (CF-4R only)

☐ Manufacturer's minimum required thickness at time of installation ______________ (inches) Manufacturer's minimum required settled thickness ______________ (inches). Number of days since loose-fill insulation was installed ______________ (days). At the time of installation, the insulation shall be greater than or equal to the manufacturer's minimum initial insulation thickness. If the HERS rater does not verify the insulation at the time of installation, and if the loose-fill insulation has been in place less than seven days the thickness shall be greater than the manufacturer's minimum required thickness at the time of installation less 1/2 inch to account for settling. If the insulation has been in place for seven days or longer the insulation thickness shall be greater than or equal to the manufacturer's minimum required settled thickness. Minimum thickness measured _____________ (inches). (CF-4R only)

DECLARATION

I hereby certify that the installation meets all applicable requirements as specified in the Insulation Installation Procedures.

________	__________________________	__________________________
Item #s	Signature, Date	Title, Company Name

________	__________________________	__________________________
Item #s	Signature, Date	Title, Company Name
________	__________________________	__________________________
Item #s	Signature, Date	Title, Company Name

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ACM RESIDENTIAL MANUAL APPENDIX RI-2005

Appendix RI – Procedures for Verifying the Presence of a Thermostatic Expansion Valve or High Energy Efficiency Ratio Equipment

RI.1 Purpose and Scope

The purpose of these procedures is to verify that residential space cooling systems and heat pumps have the required components to achieve the energy efficiency claimed in the compliance documents. The procedures only apply when a TXV is specified for split system equipment or an EER higher than the default is claimed. For dwelling units with multiple systems, the procedures shall be applied to each system separately.

The installer shall certify to the builder, building official and HERS rater that he/she has installed all the correct components.

The reference method algorithms adjust (improve) the efficiency of air conditioners and heat pumps when field verification indicates the specified components are installed. Table RI1 summarizes the algorithms that are affected.

Table RI-1 – SUMMARY OF FIELD VERIFICATION

Field Verification Check	Variables and Equation Reference	Description	Standard Design Value	Proposed Design	
				Default Value	Procedure
Presence of a TXV	F_{TXV} (Eq. R4-40 and R4-41)	F_{TXV} takes on a value of 0.96 when the system has a verified TXV or has been diagnostically tested for the correct refrigerant charge. Otherwise, F_{TXV} has a value of 0.90.	Split systems are assumed to have refrigerant charge testing or a TXV, when required by Package D.	No TXV or refrigerant charge testing.	Section RI.2
Presence of a matched High Efficiency Compressor Unit, Evaporator Coil, Refrigerant Metering Device, and (where specified) Air Handling Unit and/or Time Delay Relay.	EER	The EER is the Energy Efficiency Ratio at 95 F outdoors specified according to ARI procedures for the matched combination	Systems are assumed to have the default EER based on SEER, see ACM Equation 4.44.	Default EER	Sections RI.3 and RI.4

RI.2 TXV Verification Procedure

The procedure shall consist of visual verification that the TXV is installed on the system.

RI.3 Time Delay Relay Verification Procedure

When a high EER system specification includes a time delay relay, the installation of the time delay relay shall be verified.

The procedure shall be:

1) Turn the thermostat down until the compressor and indoor fan are both running.

2) Turn the thermostat up so the compressor stops running.

3) Verify that the indoor fan continues to run for at least 30 seconds.

RI.4 Matched Equipment Procedure

When installation of specific matched equipment is necessary to achieve a high EER, installation of the specific equipment shall be verified.

The procedure shall consist of visual verification of installation of the following equipment and confirmation that the installed equipment matches the equipment required to achieve the high EER rating:

1) The specified labeled make and model number of the outdoor unit.

2) The specified labeled make and model number of the inside coil.

3) The specified labeled make and model of the furnace or air handler when a specific furnace or air handler is necessary to achieve the high EER rating,

4) The specified metering device when a specific refrigerant metering device (such as a TXV or an EXV) is necessary to achieve the high efficiency rating.